TATA ENERGY RESEARCH INSTITUTE
BANGALORE

COMPREHENSIVE ENERGY AUDIT REPORT

OF

NATIONAL ALUMINIUM COMPANY LTD.
SMELTER PLANT, ANGUL
ORISSA

" CARBON PLANT "

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NATIONAL ALUMINIUM COMPANY LIMITED
SMELTER PLANT, ANGUL
ORISSA

"CARBON PLANT"

"Comprehensive Energy Audit Report"

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This section presents a summary of recommendations contained in the main report. The main report contains a comprehensive and complete analysis and recommendations emerging from the detailed energy audit study of Carbon Plant.

2.0 PRODUCTION AND ENERGY CONSUMPTION PROFILE

The carbon area produces various products such as Green anodes, baked anodes rodded anodes. The annual production for the three years period 1993-94, 1994-95 and 1995-96 are as follows.

Product	Unit	Year	
		1995-96	April 96 - Feb 97
Green Anodes	Mt	126422	111451
Baked Anodes	Mt	113329	104592
Rodded Anodes	Nos.	104820	99675

The total annual Heavy fuel oil and power consumption for the Carbon plant for the period 1995-96, April 96- Feb 97 are as given below.

Year	Electricity consumption	HFO consumption
	(Million kWh)	(Kilo litres)
1995-96	20.7799	9846
April 96- Feb 97	21.5725	8993

In general, both power and HFO consumptions have shown an upward trend over the years. HFO and electricity consumption constitute about 47% and 0.69% of the total consumption of the entire complex. The total energy bill (HFO and Electricity) for the Carbon plant for the year 1995-96 was of the order of approximately Rs.922 lakh.

3.0 SUMMARY OF ENERGY SAVING POTENTIAL

A summary of table giving the potential savings and payback on investment is given below. List of retrofits and their suppliers addresses are given in Appendix -7/1.

Area	Energy savings		Cost savings	Cost of implementation	Simple payback period
	kL/yr	Lakh kWh/yr	Rs.Lakh/yr	Rs.Lakh	Years
Electric Drives	-	4.66	4.05	14.53	3.6
Thermic Fluid Heater	120	-	8.95	3.0	0.33
Fans and Blowers	-	6.64	5.78	Marginal	Immediate
Total	**120**	**11.30**	**18.78**	**17.53**	**0.93**

Total energy savings (both HFO and Electricity) in the carbon plant by implementing the various measures are estimated at Rs.18.78 lakh per annum with an investment of Rs.17.53 lakh. The savings potential and payback period calculations are based on the present cost of power and heavy fuel oil . The saving potential and payback will increase with increase in energy cost. Most of the recommendations are attractive with a simple payback period of less than a year.

4.0 ELECTRIC DRIVES

A. Installation of Energy Efficient Motors

The standard efficiency motors in the range of 18.5 kW - 125 kW operating at 60 - 70% load, should be replaced with energy efficient motors. Action should be initiated to procure and replace all Standard efficiency motors with high efficiency motors as and when the motors are reported to have been rewound more than 3 to 4 times. The implementation of the above measure is expected to yield annual energy savings of 4.07 lakh kWh with a simple payback period of 3.07 years. (Section 3.2.B).

B. Auto Delta Star Operation of Bucket Elevators & Conveyors

Bucket elevators and conveyor motors in the range of 7.5 kW - 30 kW are loaded in the range of 35 - 40%. Auto DELTA-STAR controllers should be adopted (operates in star mode when the motor is under loaded and changes over to delta mode when the motor load exceeds 40%) for the above motors. This measure yields energy savings of 0.24 lakh kWh with other system benefits and a simple payback period of 9.1 years. (Section 3.2.C).

C. Use of P.F.Controller/Electronic Soft Starters for Motors

Hydraulic power pack motors have to be connected with electronic energy savers (Section 3.2.D) in view of many system benefits mentioned below :

- Improved p.f. of operation of motors at all varying load cycles (upto 0.90).
- Reduces starting surge by way of sampling the voltage wave form.

- Energy savings due to reduction in magnetic losses.
- Minimise mechanical wear and tear of drive and driven parts.
- Reduced heating of motor (improved operating efficiency).
- Improved p.f. (reduced kVAr demand on system).

D. Thermostatic Controller for Anode Cooling Water Circuit

Automatic thermostatic controller should be installed for green anode cooling water system. This measure yield annual energy savings of 0.35 lakh kWh with simple payback period of 0.67 years. (Section 3.2.E).

5.0 BAKING OVENS

A. Arresting Air Ingress in Anode Preheating Sections

Air Infiltration in anode preheating sections should be arrested by covering with aluminium foil. By avoiding air infiltration temperature of anodes will increase at faster rate and subsequently temperatures of flue gas will increase. This also avoids fire hazards. (Section 4.2.~~C)~~.B)

B. Replacing the Existing Cast Iron Thermocouple Lead Covers with Refractory Material

The measured surface temperatures of thermocouple lead covers is 115°C to 120°C. Due to high surface temperatures, plastic sheet at preheating anode section is melting. By replacing cast iron thermocouple lead cover with refractory material air ingress can be avoided. (Section 4.2.~~B)~~. C)

6.0 THERMIC FLUID HEATER

Controlling the Excess Air in the Thermic Fluid Heater

The measured CO_2 percentage in thermic fluid heater is 4.5% which corresponds to high excess air. The optimum percentage of CO_2 in flue gases should be around 12-13%. This value can be achieved by periodic monitoring and controlling of CO_2 or O_2 percentage by incorporating modulator system. Hence the excess air losses should be effectively controlled by reducing the excess air quantity by changing the existing modulator to control blower damper. This measure is expected to result in annual HFO savings of 120 kL. (Section 5.2 B).

7.0 FANS AND BLOWERS

A. Arresting Air Infiltration in ID Fans Circuit in Bake Oven

Flow measurement was done to know the quantity of exhaust flue gases from bake oven after combustion. The measured value indicates a flow of 3,26,260 Nm^3/h as against the design value of flue gases after combustion of 1,60,000 Nm^3/h. This difference of 1,66,260 Nm^3/h between measured value & design value is due to the air infiltration in fans circuit. 30% of this air infiltration should be arrested resulting in considerable energy savings.

This measure is expected to save 6.64 lakh kWh or Rs.5.78 lakh annually, with marginal investment. (Section 6.2.B).

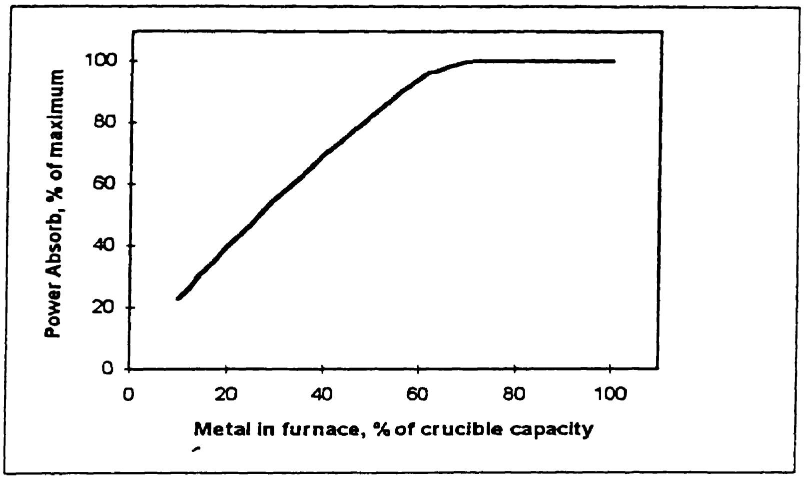
8.0 INDUCTION FURNACES

A. *General*

1. Induction furnace current balancing is carried out manually. Auto balancing of currents is suggested for balanced loading of furnace transformer.
2. Panel meters for Furnace II & III needs to be calibrated, if necessary replaced for better monitoring of power usage.

B. *Induction Furnace II & III (Rodding Shop)*

1. Optimum cycle time 1:30 min has to be maintained.
2. To know liquid metal temperature for pouring infrared thermometers can be used. By temperature measurement over-shooting can be avoided, extra amount of energy required for over shooting can be cut down.
3. Present ladle capacity is 0.8 tonnes. The quantity of slag formation during melting operation is around 10%. By providing one induction furnace of 5 - 6 ton and maintain heel two-third of volume, 5-7% energy savings is possible. The below graph gives the relation between power absorbed and metal held in crucible of a mains frequency coreless furnace.



For higher capacity furnace, surface heat losses are less compared with smaller furnace capacity.

For higher capacity induction furnace installation, detailed engineering has to be carried out.

MAIN REPORT

NATIONAL ALUMINIUM COMPANY LIMITED
SMELTER PLANT, ANGUL

COMPREHENSIVE ENERGY AUDIT REPORT

" CARBON PLANT"

1.0 INTRODUCTION

This report presents the results of the Comprehensive Energy Audit study carried out during February- March 1997.

The study focussed on the following major energy consuming areas in the carbon plant to identify energy conservation opportunities.

- Electric Drives
- Baking Oven Furnaces
- Thermic Fluid Heater
- Fans and Blowers

During the study, every attempt was made to understand the operational features and working of the project in proper perspectives. For the purpose of analysis, various operations, the equipments were observed, relevant data collected and measurements were taken wherever necessary using sophisticated portable instruments. There was constant interaction with the plant personnel who gave full support to the study team. This report presents the analysis, findings and recommendations for achieving energy savings.

2.0 PRODUCTION AND ENERGY CONSUMPTION PROFILE

2.1 PRODUCTION PROFILE

The carbon area produces various products such as Green anodes, baked anodes and rodded anodes. The annual production for the three years period 1993 - 94, 1994 - 95 and 1995 - 96 are as follows :

Year	Green Anodes (Mt)	Baked Anodes (Mt)	Rodded Anodes (Nos.)
1993 - 94	103168	113178	100253
1994 - 95	114656	-	96055
1995 - 96	126422	113329	104820

By and large, it can be observed that there is an increasing trend in production of various anodes over the years.

2.2 ENERGY CONSUMPTION PROFILE

ENERGY SOURCES

Electricity , heavy fuel oil, LDO and diesel are the major energy sources to the carbon plant. The total annual HFO and power consumption for the past three years are given below :

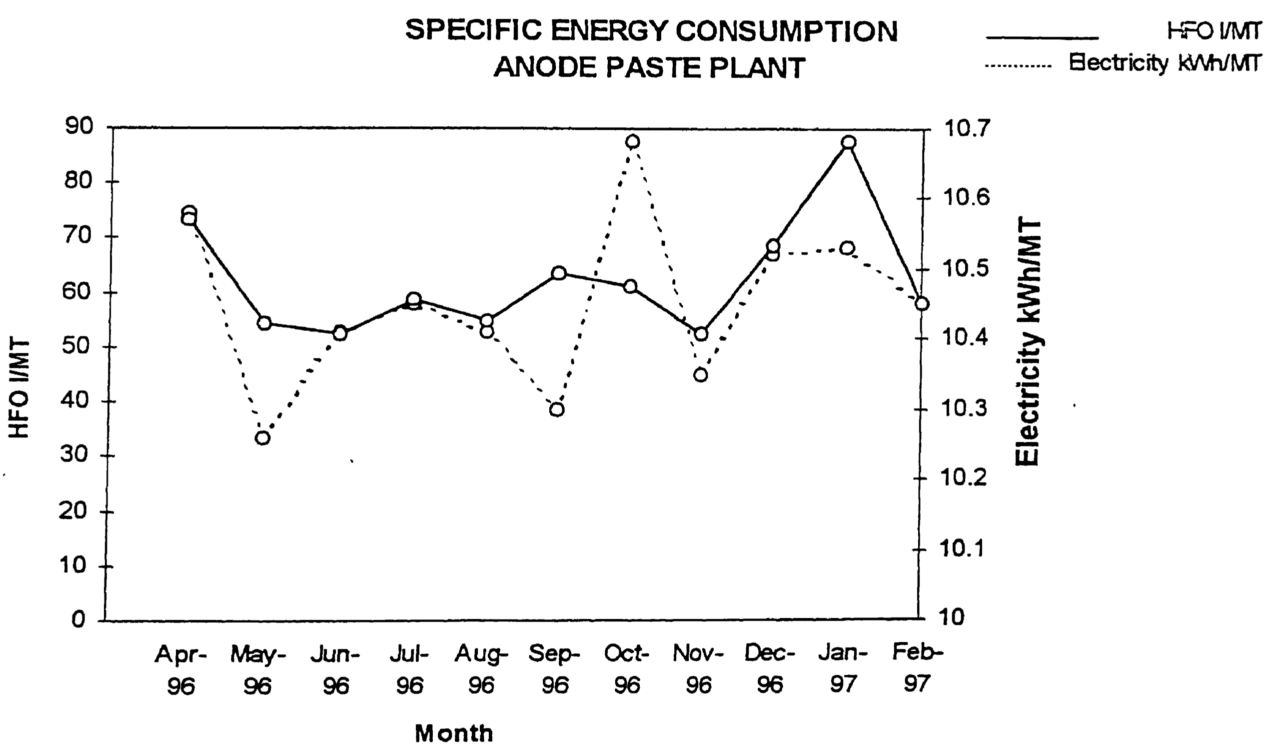
Year	Power consumption Million kWh	* HFO Consumption kL
1993 - 94	17.2186	8796
1994 - 95	19.57	9072
1995 -96	20.7799	9846
April 96 - Feb 97	21.5725	8993

* In baking oven and anode paste plant respectively

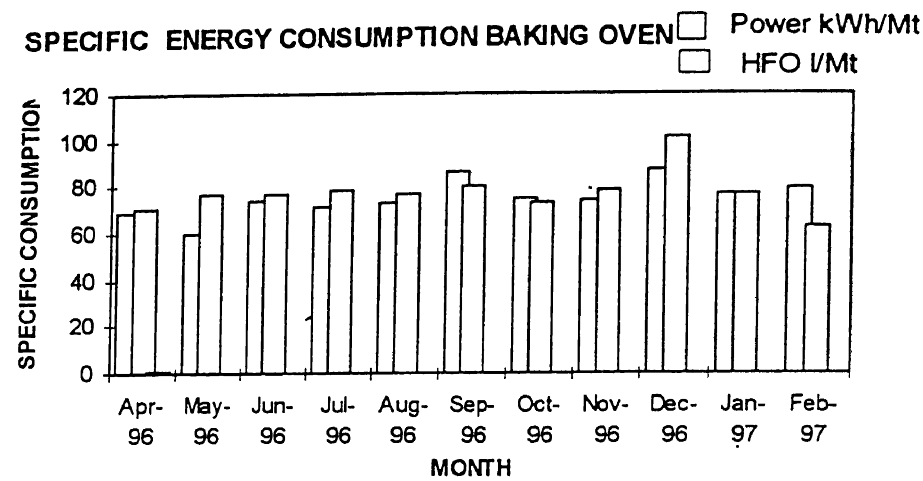
In general, both power and HFO consumptions have shown an upward trend over the years.

Monthwise production, specific electricity, LDO and HFO consumption for the period April 96 - Feb 97 for the anode paste, baking oven and rodding plants are exhibited below :

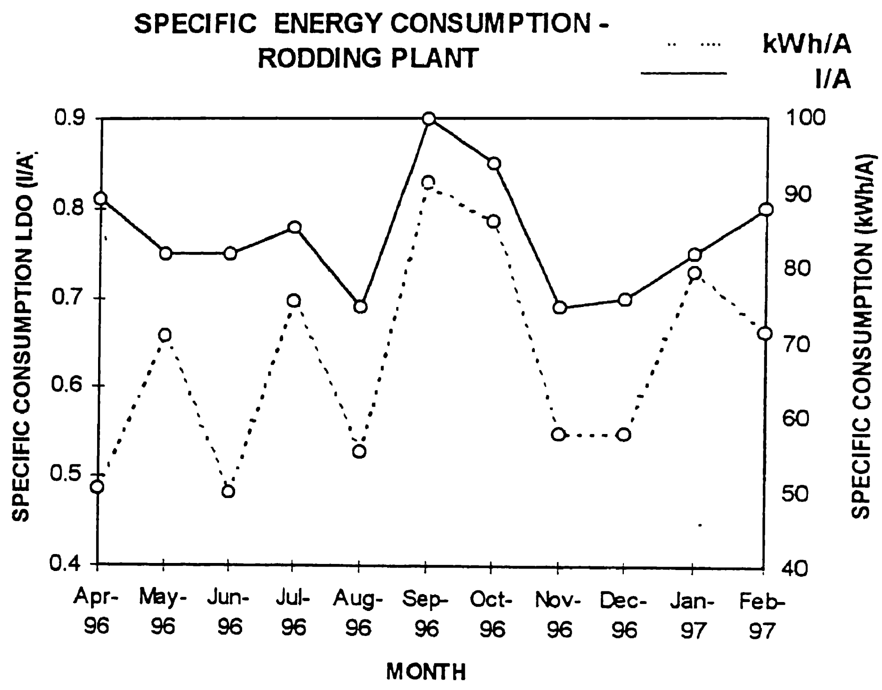
Anode Paste Plant :



Baking Oven

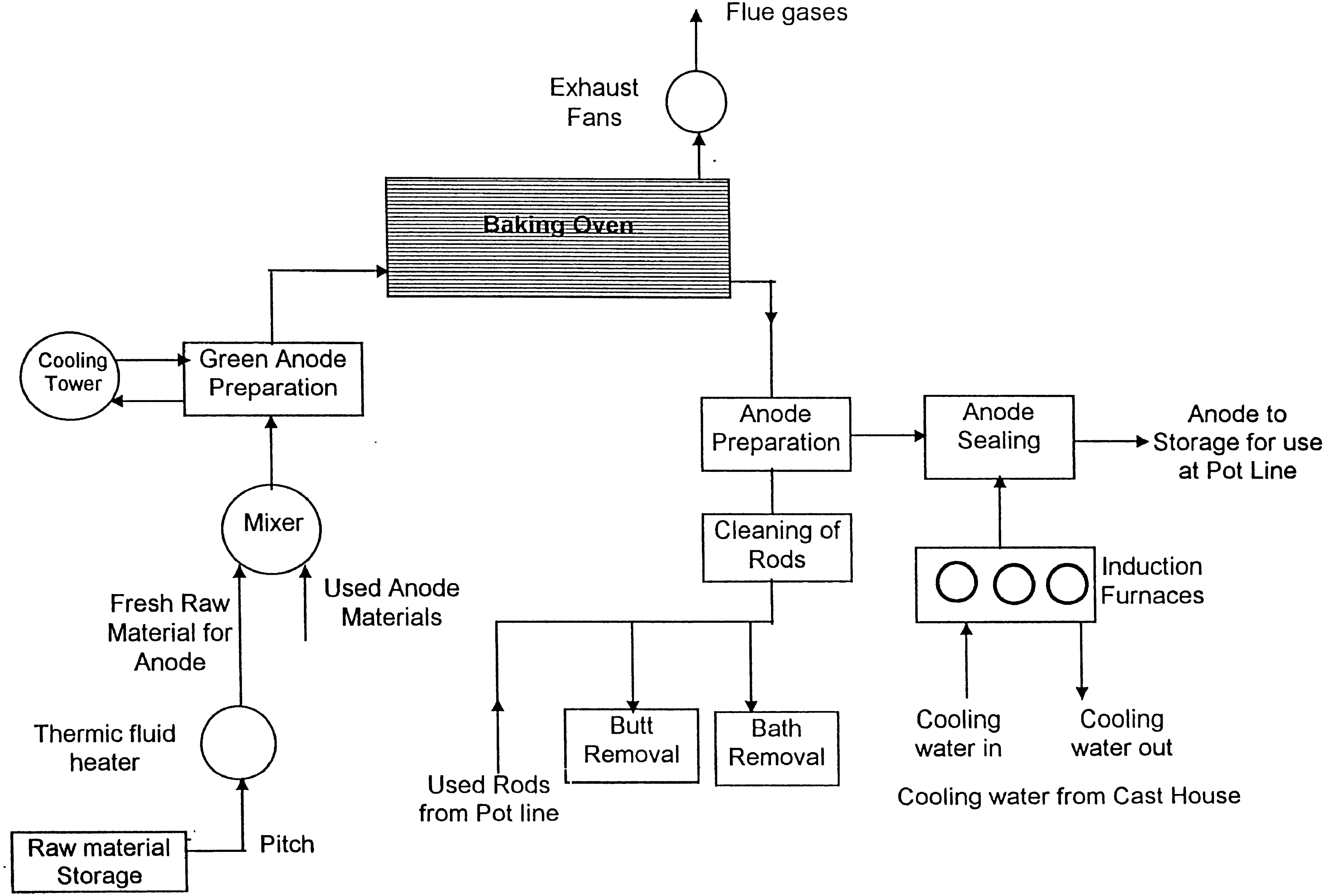


Rodding Plant



Details are given in Appendix - 2/1.

FLOW CHART OF CARBON PLANT



3.0 ELECTRIC DRIVES

The study covers LT & HT motors coupled to drives of carbon plant comprising of following areas.

- Anode Paste Plant
- Bake Oven Plant
- Rodding Shop

The discussions also include supply voltage systems for drives.

3.1 FACILITY DESCRIPTION

A. Anode Paste Plant

The LT drives comprise AC motors driving auxiliaries of sections like coke-fractionating, vibro-compacting, boiler and htf, dedusting, pitch handling & anode-handling etc. The AC motors of 11 kW - 132 kW rating and one H.T. motor of 400 kW, operating on 6.6 kV were taken for analysis.

B. Bake Oven Plant

The drives of rating upto 75 kW are coupled to air blowers, cranes and vacuum pumps.

C. Rodding Shop

The motors upto 132 kW rating in operation are coupled to hydraulic power packs, crushers, conveyors, dedusting fans etc. The H.T motors of 480 kW rating coupled to de-dusting fans (3 nos.) receive supply through, step- down transformers at 11 kV / 6.6 kV.

3.2 OBSERVATIONS ANALYSIS & FINDINGS

The drives include use of standard efficiency motors and imported high efficiency motors obtained along with original equipments.

A. Loading Pattern

The operating parameters like motor load in kW, ampere loading and PF operation, have been measured for motors above 11 kW, using hand held power analyser. Measured parameters are given in Appendix - 3/1.

(I) ANODE PASTE PLANT

<u>Coke Fractionating Section</u>

- The bucket elevator drives of 18.5-37 kW are loaded less than 60%.
- The 132 kW mixer motor is loaded upto 40%.
- The fans are loaded between 60 -100%.
- The operating p.f of these drives is above 0.68 lag.

Vibro Compacting Unit

- The 55 kW motor coupled to vibro-compacting mould 1& 2 are loaded between 60 - 70 %, and during no-load cycle, they are loaded less than 12%.

- The 90 kW hydraulic power-pack motor is loaded upto 90 % and loaded to 10% during no-load cycles.

The load & no-load cycles were observed to be between 67 secs. & 15 secs.

Boiler & H.T.F

➲ The melter and circulating pumps are loaded over a wide range i.e. 23 - 81%, depending upon the utilisation areas.

➲ The pre-heating & plug screw pumps are loaded upto 60 %. All the pumping systems have 100% standby.

Pitch Handling System

- The belt conveyor & hammer crusher motors are loaded upto 70%.
- The melter mixer of 37 kW rating is loaded to 47%.

Anode Handlin• Zone

- The cooling tunnel pumps of 37 kW are loaded beyond 90%.
- The C.W pumps having standby, are loaded above 70%.
- CT fans of 9 kW rating are lightly loaded.(<31%).
- The steam exhaust fans &hot-well pumps are loaded optimally.
- The green anode lifting motor of 66 kW is loaded > 100%.

The details of measurements carried out for all the above operations are given in Appendix - 3/1.

(II) Bake Oven Plant

- The air blowers of 30 kW rating are loaded between 52-78% with dampers in open position.
- The FTA crane - vacuum pump motors of 75 kW rating is loaded less than 27%. After preventive maintenance of system, the load on the motor got reduced to 20%. However the duty cycle is very stringent.

III. Rodding Shop

- The hydraulic power packs of 22 kW rating, are loaded to > 80 %.
- The furnace auxiliaries are loaded optimally i.e. around 60%.
- Bath conveyor motors are loaded between 33-70 % with p.f as low as 0.46.
- Impact and jaw crushers are loaded to optimum.
- All other motors coupled to conveyors & fans are loaded as per plant production systems in line (loads varying from 20-80 % observed).

B. Application of Energy Efficient Motors

The carbon plant machine motors (few are energy efficient) & auxiliary drives have standard motors, loaded between 60-90 %. Some motors have been rewound two or three times during their last 10 years service.

Energy efficient motors (High Efficiency Motors) manufactured by reputed manufacturers operate with reduced losses, affording similar operating characteristics for the same frame size. However these motors are 30-40 % costlier than standard efficiency motors. Some of the motors have been identified for replacement with energy efficient motors. The 30 kW motors of air blowers have to be replaced with high efficiency motors. It is also proposed to tryout 22 kW high efficiency motor for one of the blowers.

Implementation of this proposal is expected to give annual energy savings of 4.07 lakh kWh with an investment of Rs.1.24 lakh. Sample calculation and techno-economic details are worked out in Appendix - 3/2.

However, sufficient records pertaining to number of rewounds of motors, would assist in timely action plan for replacement.

C. Auto Delta Star Operation of Motors Coupled to Bucket Elevators and Conveyors

The observations of motors coupled to bucket elevators & conveyors indicate that the load on motors vary from 30 % to 70 % depending on plant production/process. The drive motors of 7.5 kW - 30 kW bucket elevators and conveyors are observed to have less than 40% load during their cyclic loading period.

Equipment details	Rated kW	Measured kW
BUCKET ELEVATOR		
M-7	30	19.20
M-97	18.5	3.66
M-36	18.5	5.79
BELT CONVEYOR		
M-204	15	3.7
M-133	18.5	6.75
M-66	15	2.94
M-164	15	1.83
M-165	7.5	1.59
C-1 Conveyor	15	4.29
C-11 Conveyor	11	3.03

The p.f of operation of such drives is observed to be low i.e. between 0.4 to 0.6 and such an operation results in losses, which can be minimised by star mode operation, during underloaded periods. These motors should be operated in star mode whenever the load on motor falls below 40%. However when load increases, then automatic starter senses the rise in load current and quickly restores motor to delta mode. Hence it is suggested to install such controllers for the drives identified in above table.

Implementation of the above proposal is expected to give annual energy saving of 0.24 lakh kWh with a simple payback of around 9.1 years. However, in view of proposal not being attractive, plant management should view the implementation aspects by considering additional system improvements, maintenance effort required etc. Details are given in Appendix - 3/3.

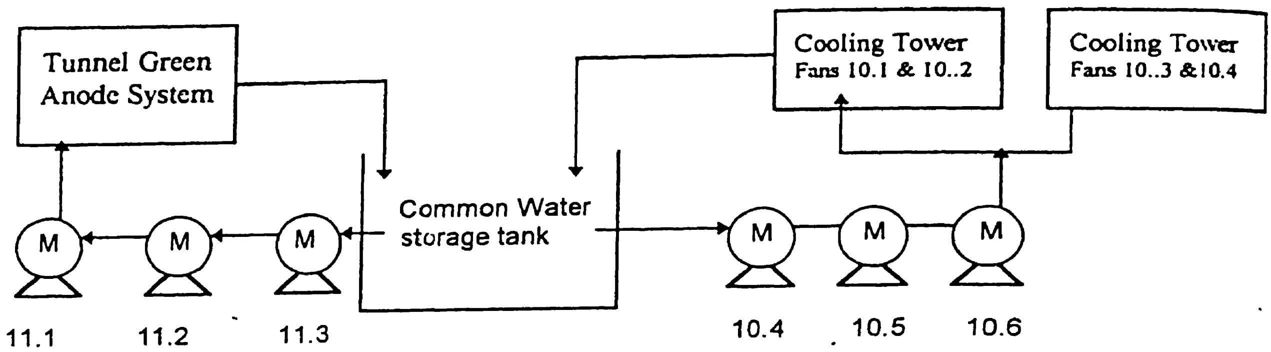
D. Use of PF Controllers / Electronic Softstart Energy Savers

The motors coupled to hydraulic machines like thimble press and vibro-compacting machines have a cyclic load/no load operation. In such cases application of electronic energy savers are a preferable choice. Electronic energy savers save energy by controlling the voltage of operation to the motors sensing the load on the motor. During load and no load cycle, these starters vary the voltage by as much as 15% and save energy with the best protection features. Implementation of this proposal though not techno-economically attractive, it has to be viewed in terms of reduced ampere loading of motor during load/unload cycles, improved pf of operation/less heating of motor), reduction in kVA load on transformers. The details of calculations are worked out in Appendix - 3/4.

E. Thermostatic Control for Anode Cooling Water Circuit

Cooling water pumps 11.1, 11.2, 11.3 of 37 kW rating provide cooling water for cooling of green anodes. Two of these pumps are operated and one number is standby. CW pumps 10.4, 10.5, 10.6 of 18.5 kW each pump under closed circulation through cooling tower. There are four CT fans 10.1, 10.2, 10.3 & 10.4 of 9 kW each.

The schematic diagram is given below :



Whenever the temperature of the storage water in the common tank rises, two nos. out of 3 nos. of these closed loop circulating pumps and two nos. of CT fans (out of 4 nos.) are switched on manually for cooling.

Automatic thermostatic control which is a preferable choice can be provided to switch on and switch off the circulating pumps and CT fans which would yield energy savings. The above proposal is expected to yield an annual energy saving potential of 0.35 lakh kWh with an investment of Rs.0.2 lakh. Appendix - 3/5 represents the techno-economics of the same.

D. H.T MOTORS

The H.T motors coupled to ball mill & de-dusting fan systems comprise of 1 x 400 kW motor & 3 x 480 kW motor at 6.6 kV. The 6.6 kV motors derive supply by 1250 kVA transformers at 11/6.6 kV level. The details of loading pattern observed for a typical working day, are given in Appendix - 3/6.

The readings taken using a power analyser are with reference to 6.6 kV system .

Application/ Connected Equipment	Motor							% Loading	Frequency Hz
	3 Phase Parameter								
	Rated kW	Volts V	Amps A	P.f. Cos ϕ	kVA	kW	kVAr		
Ball Mill	400	6900	27.3	0.75	314	242	208.1	60.5	50.1
ID Fan - 1	480	6960	32.4	0.71	399	282	280.9	58.8	51 0
ID Fan - 1	480	7170	36.0	0.78	448	347	280.3	72.3	51 1
ID Fan - 1	480	7170	37.6	0.79	469	370	287.5	77.1	51.3
ID Fan - 3	480	7170	34.0	0.76	423	326	274.9	67.9	51 9

Referring to detailed measurements carried out , it is observed that the voltage levels on 6.6 kV bus is as high as 6.90 to 7.17 kV and frequency between 50.1 to 51.9 Hz.

The increase in supply voltage levels on 6.6 kV bus system were observed to be due to off load tap settings of 1250 kVA transformers set for o/p of 6.9 kV at mid tap - i.e. No.4. This is also due to manual operation of tap changer on 37.5 MVA auxiliary transformer. Details of offload tap positions on 1250 kVA, 11/6.6 kV transformers are given below.

Transformer Feeder - Ref.	Ref.Rating of Transformer (in kVA)	Tap Position
Ball Mill - 149	1250	4
I.D Fan1 -153	1250	4
I.D Fan 3 -154	1250	4

By optimising voltage levels, the motor heating and magnetic losses in the drives (due to the supply voltage being on higher side) will reduce if the motor 6.6 kV bus voltage is set to 100% value; The increase in voltage beyond 100% also reduces slip and hence power consumption; The additional power consumption is also due to higher grid frequency, (upto 52.0 Hz recorded) which is due to grid supply conditions during the day. The rpm of fans were observed to be 1024 rpm against 984 rpm (rated). However, during evening peaks, the frequency has been observed to be between 49-50 Hz.

The voltage levels measured and the effect of optimising the distribution system voltage for energy efficient operation of H.T motors are dealt in detail in the report of cast-house (utilities). The above measure is expected to yield energy savings and large system benefits like :

- Reduction in active loading by 2-2.5%.
- Reduction in kVA loading of transformers.
- Marginal improvement in PF of load.
- Cooler operation of motors.

After implementation of above proposal, at main receiving station , the 6.6 kV supply should be ensured to be at 100 % value. If supply voltage is still higher, action / decision should be taken to alter the offload tap position of transformers (by suitably changing the offload taps provided, which are presently at centre tap No. 4).

A detailed exercise has to be planned twice in a year to log the offload tap positions and simultaneous voltage measurements for optimum bus voltage co-ordination for LT/HT drives.

3.3 RECOMMENDATIONS

A. Installation of Energy Efficient Motors

The standard efficiency motors in the range of 18.5 kW - 125 kW operating at 60-70 % load, should be replaced with energy efficient motors. Action should be initiated to procure and replace all Standard efficiency motors with high efficiency motors as and when the motors are reported to have been rewound more than 3 to 4 times.

The implementation of the above measure is expected to yield energy savings as given below. (Section 3.2 B).

Annual energy savings	=	4.07 lakh kWh
Annual cost of energy savings	=	Rs.3.54 lakh
Cost of implementation	=	Rs.12.4 lakh
Simple payback period	=	3.07 years

B. Auto Delta Star Operation of Bucket Elevators & Conveyors

Bucket elevators and conveyor motors in the range of 7.5 kW - 30 kW are loaded in the range of 35 - 40%. Auto DELTA-STAR controllers should be adopted (operates in star mode when the motor is under loaded and changes over to delta mode when the motor load exceeds 40%) for the above motors. This measure yields energy savings of 0.24 lakh kWh with other system benefits (Section 3.2.C).

Annual energy savings	=	0.24 lakh kWh
Annual cost of energy savings	=	Rs.0.21 lakh
Cost of implementation	=	Rs.1.93 lakh
Simple payback period	=	9.1 years

C. Use of P.F.Controller/Electronic Soft Starters for Motors

Hydraulic power pack motors have to be connected with electronic energy savers in view of many system benefits. (Section 3.2. D).

D. Thermostatic Controller for Anode Cooling Water Circuit

Automatic thermostatic controller should be installed for green anode cooling water system. This measure yield energy savings as given below. (Section 3.2 E).

Annual energy savings	=	0.35 lakh kWh
Cost of annual energy savings	=	Rs.0.30 lakh
Cost of implementation	=	Rs.0.20 lakh
Simple payback period	=	0.67 years

3.4 SUMMARY OF POTENTIAL SAVINGS

Sl. No	Proposal	Energy Savings (in lakh)		Cost of implementation	Simple payback period
		kWh/yr	Rs.lakh/Yr	Rs. (lakh)	Years
1.	Energy efficient motors	4.07	3.54	12.4	3.07
2.	Auto delta star operation of motors	0.24	0.21	1.93	9.1
3.	Thermostatic controller for anode cooling water system	0.35	0.30	0.20	0.67
Total		4.66	4.05	14.53	3.6

4.0 BAKING OVEN

4.1 FACILITY DESCRIPTION

Baking is the process of gradually heating green anodes to about 1050 °C. During this process, pitch is converted to coke which binds the aggregate grains together into a monolith. Electrical conductivity and mechanical strength of the anode is increased by baking.

Anode baking is carried out in bake ovens which consists of 84 sections. Each section consists of six muffles, 12 green anodes are packed in each muffle i.e. 72 anodes per section. Anodes are covered with calcined petroleum coke to protect them against air burning. After coke covering, a plastic sheet is used to cover the section to prevent ingress of air.

Bake ovens consists of four burner ramps. Each burner ramp consists of 14 burners placed over a section on "firing". Thermocouple ramp measures the flue gas temperature and anode temperature which is used to control the fuel oil injection through a microprocessor. The rate of heating and final temperatures are programmed into the burner control panel. Average heavy fuel oil consumption in bake oven is 1.0 kL per hour.

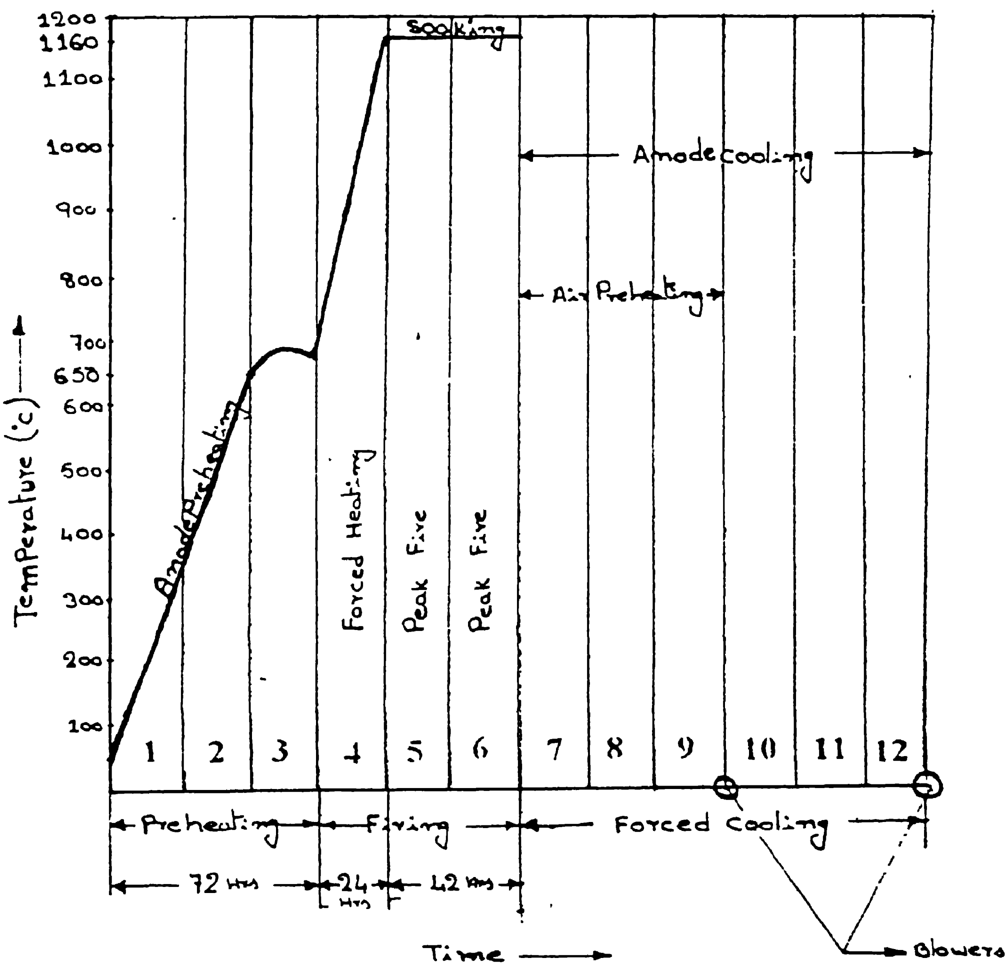
4.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Loading Pattern of Baking Oven

It is observed that in each fire the number of sections and activities are given below :

No. of Sections	Activity
3	Combustion air preheating
3	Firing (Forced firing - 1, Soaking -2)
3	Anode preheating

Each section consists of six muffles. Walls of the muffles are hollow with built-in baffles. Hot flue gases pass through the hollow space of walls and transfer heat to the anodes through the coke cover. The bake oven cycle time Vs temperature of one fire is given below :



Combustion Efficiency of Bake Oven Firing

Various factors which affect the combustion efficiency are dry flue gas losses, heat losses due to H_2 and H_2O in fuel, heat loss due to H_2O in air, excess air losses etc. Were studied, analysed for various energy conservation measures. For the analysis parameters such as temperature of flue gas, CO_2 percentage in each wall, combustion air temperatures in each wall etc. were monitored and recorded. The observed parameters are given in Appendix - 4/1.

The overall combustion efficiency of one fire is evaluated by adopting indirect method, in which various losses are deducted from total heat input to arrive at the useful heat.

The details of calculations of combustion efficiency for one fire is given in Appendix - 4/2.

The summary of the heat balance is given below :

Particulars	Flue Wall						
	No.1	No.2	No.3	No.4	No.5	No.6	No.7
HEAT INPUT							
Through heat value of fuel	66.53	73.44	65.03	69.72	67.40	70.69	64.75
Sensible heat in fuel	0.11	0.12	0.10	0.09	0.09	0 11	0.10
Sensible heat in combustion air	33.36	26.44	34.86	30.20	. 32.52	29.20	35.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
HEAT OUTPUT							
Dry flue gas losses	5.97	5.01	6.52	5.66	6.05	5.24	6.50
Heat loss due to H_2 in fuel	4.43	4.89	4.33	4.64	5.00	4.71	4.31
Heat loss due to moisture in fuel	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Heat loss due to moisture in air	0.19	0.16	0.21	0.18	0.19	0.17	0.21
Useful and unaccounted losses	89.36	89.89	88.89	89.47	89.23	89.84	88.94

B. Arresting Air Infiltration in Anode Preheating Sections

The analysis of percentage of CO_2 in exhaust flue gas in anode preheating section is as follows :

Flue Wall No.	Measured CO_2 %		
	Section 60	Section 61	Section 62
1.	8.0	4.5	3.0
2.	10.0	9.5	7.5
3.	7.5	7.5	4.5
4.	11.0	11.0	8.5
5.	11.0	10.5	8.5
6.	8.5	8.5	7.5
7.	8.5	7.5	4.0

Progressive reduction in CO_2 values indicate infiltration of air. For the above percentage carbon dioxide corresponding excess air percentage and flue gas quantity are given below :

Flue Wall No.	Corresponding Excess Air %			Flue Gas Quantity kg	
	Section 60	Section 61	Section 62	Section 60	Section 62
1.	95.10	246.85	420.28	27.89	72.71
2.	56.08	64.3	108.11	22.51	29.69
3.	108.11	108.11	246.85	29.69	48.81
4.	41.89	41.89	83.63	20.56	26.31
5.	41.89	48.65	83.63	20.56	26.31
6.	83.63	83.63	108.11	26.31	29.69
7.	83.63	108.11	290.21	26.31	54.78

The details of calculations are given in Appendix - 4/3. The quantity of air infiltration at anode preheating section is quite substantial. This air ingress results in decrease in temperature of anodes under preheating and subsequently lowering of temperature of flue gas. It is observed temperature at the exit is as low as 120 °C. This being lower than allowable temperature of 180 °C (i.e. acid dew .point) which causes corrosion and fire hazards. By covering with aluminium foil, air ingress from anode preheating sections can be avoided (or) the present practice of covering with plastic sheet has to be continued to minimise air ingress.

C. Replace Existing Cast Iron Thermocouple Lead Covers

It is observed that huge quantity of air infiltration is taking place at preheating anode sections which are under vacuum. Present practice is to avoid air ingress to preheating anode sections by covering with plastic sheet. Cycle time for anode preheating is 66 - 72 hours. The measured surface temperatures of thermocouple lead cover is 115 °C - 125 °C. Due to this high temperature, within 30 - 45 minutes, the plastic sheet above the thermocouple lead cover is melting. Air infiltration is taking place through the holes formed above the thermocouple lead covers. Temperature drop due to air ingress is to the extent of 259 °C. To avoid this air ingress, replacing the iron thermocouple lead covers with refractory material is desirable. The details of flue gas temperature drop to air ingress are given in Appendix - 4/4.

4.3 RECOMMENDATIONS

A. Arresting Air Ingress in Anode Preheating Sections

Air infiltration in anode preheating sections should be arrested by covering with aluminium foil or continuing the present practice of covering with plastic sheets. By avoiding air infiltration temperature of anodes will increase at faster rate and subsequently temperatures of flue gas will increase. This also avoids fire hazards. (Section 4.2.~~C)~~.B)

B. Replacing the Existing Cast Iron Thermocouple Lead Covers with Refractory Material

The measured surface temperatures of thermocouple lead covers is 115 °C to 120 °C. Due to high surface temperatures, plastic sheet at preheating anode section is melting. By replacing cast iron thermocouple lead cover with refractory material air ingress can be avoided. (Section 4.2 ~~D)~~. C)

5.0 THERMIC FLUID HEATER

5.1 FACILITY DESCRIPTION

In the Carbon Area, Anode Paste plant section consists of one thermic fluid heater (oil tube boiler). The capacity of thermic fluid heater is 3.2 lakh kcal/h. Heavy fuel oil is used as fuel and heat transferred to the utilisation areas by a heat transferring fluid. The heat transferring fluid (HTF) circulating in a closed circuit heat exchanging network, is heated to a temperature of 225 °C - 250 °C. Average heavy fuel oil consumption is around 20 kL per week. The complete specifications of thermic fluid heater is given in Appendix - 5/1.

5.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Heat Balance and Efficiency of the Thermic Fluid Heater

Trials were conducted to evaluate the combustion efficiency and heat balance of thermic fluid heater.

Various measurements such as flue gas temperature, CO_2 percentage in flue gas, heat transfer fluid (HTF) inlet and outlet temperature, power consumption of circulating pump, heavy fuel oil preheated temperature, dry bulb and wet bulb temperatures were measured. The observations made during the trial are given in Appendix - 5/2.

The thermic fluid heater combustion efficiency is calculated by quantifying heat losses by indirect method and given in Appendix - 5/3. The thermic fluid heater heat balance is given below :

Particulars	kcal/kg	Percentage
HEAT INPUT		
Through heat value of fuel	10252.00	89.51
Sensible heat in fuel	16.50	0.14
Sensible heat in combustion air	1184.70	10.34
Total	11453.20	100.00
HEAT OUTPUT		
Dry flue gas losses	2625.32	22.92
Heat loss due to H_2 in fuel	710.33	6.20
Heat loss due to moisture in fuel	6.86	0.06
Heat loss due to moisture in air	83.35	0.73
Useful and unaccounted losses	8027.35	70.09

B. Excess Air Control

The measured CO_2 percentage in thermic fluid heater is 4.5%. The optimum percentage of CO_2 in flue gases should be around 12 - 13%. This value can be achieved by periodic monitoring and controlling of CO_2 or O_2 percentage by incorporating modulator system. . Efficiency of thermic fluid heater before and after excess air control works out to 70.09% and 84.53% respectively. Calculation details of various heat losses and efficiency after excess air control is given in Appendix - 5/4.

Summary of heat losses and efficiency with and without excess air control is tabulated below :

Particulars	Before Excess Air Control	After Excess Air Control
HEAT INPUT		
Through heat value of fuel	89.51	95.85
Sensible heat in fuel	0.17	0.32
Sensible heat in combustion air	10.34	3.83
Total	100.00	100.00
HEAT OUTPUT		
Dry flue gas losses	22.92	8.50
Heat loss due to H_2 in fuel	6.20	6.64
Heat loss due to moisture in fuel	0.06	0.06
Heat loss due to moisture in air	0.73	0.27
Useful and unaccounted losses	70.09	84.53

Hence, by changing the existing modulator to operate blower damper and controlling the excess air quantity will result in annual energy savings to the tune of 120 kL of heavy fuel oil (i.e.Rs.8.95 lakh). Details are given in Appendix - 5/5.

C. Insulation Survey at HTF Utilisation Areas

The detailed observations are made on all utilisation areas. Aggregate fraction containing butts, coarse, medium and fines are mixed and heated to about 150 °C in the "preheating screw". Molten pitch drawn from a storage tank kept at a suitable temperature is mixed with aggregate fractions in a "Mixer" to make "green paste". The "preheating screw", mixer "pitch Melter", "pitch storage tank" are jacketed with heat transfer fluid. The details of observed temperatures are given in Appendix - 5/6.

A detailed survey was carried on various distribution lines. All heat transfer fluid (HTF) lines were adequately insulated and the status of insulation was found to be satisfactory. The observed surface temperatures are in the range of 28 °C to 38 °C. The measured surface temperatures are given in Appendix- 5/7.

5.3 RECOMMENDATIONS

Controlling the Excess Air in the Thermic Fluid Heater

The excess air losses should be effectively controlled by reducing the excess air quantity, by changing the existing modulator to control blower damper. This measure is expected to result in annual HFO savings of 120 kL . (Section 5.2.B).

Energy savings	=	120 kL /y
Cost savings	=	Rs.8.95 lakh/y
Investment required	=	Rs.3.0 lakh
Simple payback period	=	0.33 years

5.4 SUMMARY OF POTENTIAL SAVINGS

Sl. No.	Proposal	Annual savings		Investment required	Simple Payback period
		Fuel savings kL	Cost savings Rs.lakh	Rs. lakh	(Years)
1.	Controlling the excess air in the thermic fluid heater	120	8.95	3.0	0.33

6.0 FANS AND BLOWERS

6.1 FACILITY DESCRIPTION

In bake oven, both induced draft fans and forced draft fans (blowers) are used. Induced draft fans are used for handling flue gases after combustion and forced draft fans are used for supplying combustion air and for cooling baked anodes. In anode paste plant, fans are used for dedusting and venting applications. The important design parameters of fans are :

Fans	Quantity (m^3/s)	Total Static Pressure (Pa)	Motor Rating (kW)
BAKE OVEN			
Induced draft fans	50.70	5003	480
Forced draft fans	9.86	1650	30
ANODE PASTE PLANT			
General dedusting fan (U115)	16.67	4756	160
Ball mill vent fan (U113)	5.56	4021	45

The design parameters of these fans are given in Appendix - 6/1, in detail.

6.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. Flow Measurement

The quantity of flue gas / air handled by fans was determined by measuring static pressure, velocity pressure (dynamic pressure) and temperature at the suction side/delivery side for fans by using L-type Pitot tube, Micromanometer and Thermocouple. For forced draft fans (blowers) in bake oven the following flow was observed.

Blower No.	Application	Design flow (Nm^3/h)	Flow Quantity (Nm^3/h)	Outlet Damper Opening (%)
420701	Combustion air	30000	21115	50
420709	Cooling baked anode	30000	37705	100
420702	Combustion air	30000	24855	50
420706	Cooling baked anode	30000	34056	100
420703	Combustion air	30000	23729	50
	Cooling baked anode	30000	35505	100
420707	Combustion air	30000	22155	50
420708	Cooling baked anode	30000	36932	100
TOTAL		240000	236052	-

It can be seen that the flow in blowers used for combustion air is less than design flow of 30,000 Nm^3/h while the flow in blowers used for cooling baked anode is more than design flow. This is mainly due to the outlet damper operation (50% opening) for combustion air blowers resulting in higher static pressure and hence lesser flow. For blowers used for cooling baked anode, the static pressure may be less than design value and hence higher flow.

For ID fans in bake oven, it was not possible to take measurements for individual fans and hence the measurements were taken at a common sample point. The measured total flow was around 123.22 m^3/s as against a design value of 101.4 m^3/s (for 2 fans). The higher value of measured flow is due to less static pressure (300 mm Wg) than design.

For dedusting and venting fans in Anode Paste plant the measurements were taken up for individual fans. The measured values are given below :

Fans	Design Flow (m^3/s)	Actual flow (m^3/s)
General dedusting fan (U115)	16.67	13.59
Ball mill vent fan (U113)	5.56	5.33

The measured parameters for ID fans and forced draft fans in bake oven and dedusting/venting fans in Anode Paste plant are given in Appendices - 6/2, 6/3 and 6/4 respectively.

METHODOLOGY ADOPTED FOR MEASUREMENT OF PARAMETERS IN FAN

For example, let us consider ID fans in Bake Oven :

1. Static pressure, Dynamic pressure (Velocity pressure) and temperature are measured at the sample point for each fan using Pitot tube, Micromanometer and thermocouple.

   The measured parameters for ID fans in Bake Oven are :

   Static pressure (at sample point)

Suction side	=	- 255 mm Wg
Delivery side	=	+ 10 mm Wg

   Static pressure (near fan)

Suction side	=	- 300 mm Wg

Dynamic pressure	=	30.59 mm Wg (rms value)
Temperature	=	89 °C
Duct diameter	=	2.55 m

2. The density of air or gas at fan inlet (sample point) can be known from N.T.P. values (1.295 kg/Nm^3 or 1.29 kg/Nm^3) by temperature and pressure correction.

Density of flue gas	=	0.54 kg/m^3 at 350 °C
	=	1.295 kg/Nm^3
Density of air	=	1.29 kg/Nm^3

Density of the gas at sample point can be known by the formula :

$$\rho_2 = \rho_1 \times \frac{T_1}{T_2} \times \frac{P_2}{P_1}$$

ρ	=	Density in kg/m^3
P	=	Pressure in mm Wg
T	=	Temperature in Kelvin
Suffix -1	=	Represents parameters at NTP
ρ_1	=	1.295 kg/Nm^3
P_1	=	1 bar = 10330 mm Wg
T_1	=	0 °C = 273 K

Suffix - 2 = Represents measured parameters at sample point

$$\rho_2 = 1.295 \times \frac{273}{(273 + 89)} \times \frac{(10330 - 255)}{10330}$$

$\therefore$ Density at sample point, ρ_2 = 0.9525 kg/m^3

3. From Dynamic pressure & density at sample point, velocity can be obtained from the formula

$$V = c\sqrt{\frac{2 \times g \times h}{\rho}}$$

Where, g = Acceleration due to gravity in m/s^2

h = Dynamic pressure in mm Wg

ρ = Density at sample point in kg/m^3

$$V = c\sqrt{\frac{2 \times 9.81 \times 30.59}{0.9525}}$$

$$= 25.10 \text{ m/s}$$

4. By knowing the area, the quantity of flow (Q in m^3/s) can be known by :

Q = A x V

A = Area (m^2)

V = Velocity (m/s)

$$Q = \frac{\Pi}{4} \times (2.5)^2 \times 25.10$$

(Internal diameter of duct = 2.5 m)

= 123.22 m^3/s

= 4,43,578 m^3/h

The quantity of flow at NTP (Nm^3/h) can be known by ;

$$= 443578 \times \frac{\text{Density of gas at fan inlet (sample point)}}{\text{Density of gas at NTP}}$$

$$= 443578 \times \frac{0.9525}{1.295}$$

= 3,26,260 Nm^3/h

Since fans operate at different conditions, in order to compare them it is essential to know the flow in Nm^3/h.

5. Theoretical power can be calculated from the formula,

$$kW = \frac{Q \times TP \times g}{3600 \times 1000}$$

Q = Flow in m^3/h
TP = Total static pressure in mm Wg
g = Acceleration due to gravity in m/s^2

Q & TP are measured parameters.

6. Actual or measured power = $\frac{\text{Theoretical Power}}{\eta_{fan} \times \eta_{motor}}$

η = Efficiency

7. Fan efficiency is the ratio of theoretical power to actual or measured power (Motor efficiency should also be taken into account.

B. Arresting Air Infiltration in ID Fans Circuit in Bake Oven

The flow measurement was done to know the quantity of exhaust flue gas from bake oven. As per the measurement the flow is 3,26,260 Nm^3/h, as against the design flow of 1,60,000 Nm^3/h. This difference in measured and design flow is due to air infiltration in the circuit. This air infiltration should be arrested by providing aluminium foil sheets in the preheating section of bake oven.

By arresting 30% of this air infiltration, the quantity to be handled by ID fans get reduced to 2,76,382 Nm^3/h. This reduction in quantity is expected to save annually 6.64 lakh kWh or Rs.5.78 lakh. The details are given in Appendix - 6/5.

C. Compressor Leakage

The leakage points of compressed air generated from main compressors is given in Appendix - 6/6.

6.3 RECOMMENDATION

A. Arresting Air Infiltration in ID Fans Circuit in Bake Oven

The flow measurement in ID fans circuit indicates air infiltration of 1,66,260 Nm^3/h. By arresting 30% of this air infiltration considerable amount of energy can be saved. (Section 6.2.B).

Annual energy savings	= 6.64 lakh kWh
Annual cost savings	= Rs.5.78 lakh
Cost of implementation	= Marginal
Simple payback period	= Immediate

6.4 SUMMARY OF POTENTIAL SAVINGS

Sl. No.	Proposal	Annual savings		Cost of implementation	Simple Payback period
		Lakh kWh	Rs.lakh	(Rs. lakh)	
1.	Arresting air infiltration in ID fans circuit in bake oven	6.64	5.78	Marginal	Immediate

INDUCTION FURNACE

FACILITY DESCRIPTION

A. Rodding Shop

Three numbers of 2.0 ton 660 kW/1050 V main frequency induction furnaces are installed to meet the need of molten cast iron required for sealing of baked anode cakes to anode rods.

Power supply requirement for the furnaces is catered through individual identical furnace transformers. The details of the furnace transformer is given below.

Furnace Transformer Details :-

No. of Transformers	3
kVA	725
Pri. Voltage	11000 V
Sec. Voltage	400/650/850/925/1050/1100/1150 V
No. of Taps	7
OLTC	No.
Vector group	Yyno

Around 3100 kVAr, 1100 V capacitors are installed for each induction furnace for power factor compensation.

Reactor of 420 kVAr, 1050 V and capacitor bank of 420 kVAr, 1000 V meet the phase balancing requirement within tolerance of ± 5%.

Induction furnace 1 & 2 are supplied by M/s.Pioneer Electric Furnace manufacturers, while furnace 3 is supplied by M/s.Vidyut Agni Furnaces Pvt. Ltd.

B. Cathode Sealing Section (Pot Line)

One number of 2 ton 660 kW / 1050 V main frequency induction furnace installed in cathode sealing section meets the requirement of molten cast iron for cathode block sealing. This furnace is also similar to the furnace in rodding shop section. The details of the furnace transformer is given below:

Transformer details

No. of Transformers	1
kVA	725
Pri. Voltage	11000 V
Sec. Voltage	400/650/850/925/1050/1100/1150 V
No. of Taps	7
OLTC	No.
Vector group	Yyno

Power factor compensation is met by capacitor bank of 3100 kVA, 1100 V, while phase balancing requirement are catered by 420 kVAr, 1050 V reactor and 420 kVAr, 1000 V of capacitor banks. This induction furnace is also supplied by M/s.Pioneer Electric Furnace manufacturer.

C. *Production Profile*

Induction Furnaces at Rodding Shop and Cathode Sealing Shop is giving liquid metal to anodes production. The number of anodes produced from these shops year/month-wise are given below:

Year/Month	Number of Anodes	
	Rodding Shop	Cathode Sealing Shop
1996-97	94309	16267
April	7492	1106
May	7468	1784
June	7854	1169
July	7934	1195
August	8202	1536
September	8182	733
October	8340	809

7.2 OBSERVATIONS, ANALYSIS AND FINDINGS

A. *Rodding Shop Induction Furnace, Power Measurement*

The power measurements were carried out using portable power and demand analyser at the furnace transformer HT incoming panel. Necessary details with respect to electrical parameters were also collected from electrical circuit drawing.

During the audit induction furnace I was not in service and was undergoing re-lining works. While furnace II was in operation and furnace III was to undergo the sintering cycle re-lining works.

Induction furnace II & III power measurements were carried out for one typical heat cycle (charge melting). The general consumption pattern, variation in current, kW, Power factor has been shown in Appendix - 7/1. The phase currents, kW, pf, with reference to time is plotted in the graphs for furnace II & III in Appendix-7/1.(a-c) & Appendix - 7/1 (i - iii).

The operational practices were observed for two cycles. During the cycle materials practices, slag removal time taken in cycle was observed and given in Appendix - 7/2. At induction furnaces - II & III, Plant metering system parameters were monitored and is represented in Appendix - 7/3. Salient features of observations are given below:

Observations	Time (min)	
	Furnace - III	Furnace - II
Material charge for 1st bucket	8.0	15.0
Materials charge for 2nd bucket	12.0	5.0
No. of Shovels	17	15
Time taken to remove slag	5.0	8.0
Total cycle time	120	133
Furnace bath temp.	1555°C	1552 °C

The measured skin surface temperatures

Location	Temp. Range (°C)	
	Furnace - III	Furnace - II
Furnace Bottom	137-144	136 - 146
Furnace Sides	47 - 49	49 - 68
Furnace Core	92 - 114	76 - 86

During the cycle, dip measurement was carried out to know the percentage of furnace volume utilisation. It is found that slag formation is 8 - 12%, After metal pouring amount of heel maintained in the furnace is around 40-50% and utilised metal for casting is 30 - 35%.

It is found, when continuous casting is in progress, ladle pouring time is around. 40 - 42 min. As the two furnaces are in operation, optimum cycle time for each furnace should not be more than 1.30 min.

Present charge handling time is around 20 min extra time of 2 minute per charge handling is observed due to crane operation. Liquid metal pouring temperatures to ladle for furnace-III is 1552°C and for furnace-II is 1555°C. Furnace- III temperature has to be maintained higher than furnace-II, due to long launder.

For measuring accurate liquid metal temperature infrared thermometers is suggested.

Induction furnace III, energy requirement for a complete sintering cycle was monitored and is observed to be 826 kWh during the sintering period of approx. 14:00 hrs.

B Cathode Sealing Induction Furnace Power Measurements.

Induction furnace power measurements were carried out at the furnace supply panel. The general consumption pattern, variations in phase, voltages & currents, kW, pf, kVA, kVAr has been shown in Appendix - 7/4. The voltage, phase current, kW, pf with reference to time is plotted in the graphs represented in Appendix - 7/4 (a-d).

Cathode sealing induction furnace operation is according to down stream requirement. This induction furnace has load of 10 pots lining per month. In

addition, it meets liquid metal requirements for making anodes with imported anode blocks.

Furnace power is fixed at 2nd tap position and operated at low and high mode. During melting operation high tap position is maintained and while on holding low tap position is maintained respectively. Plant metering system parameters for furnace was monitored and the same is given in Appendix - 7/5.

The cooling water circuit outlet water temperatures during cycle were also monitored for the above Induction furnaces are given in Appendix - 7/6.

7.3 RECOMMENDATIONS

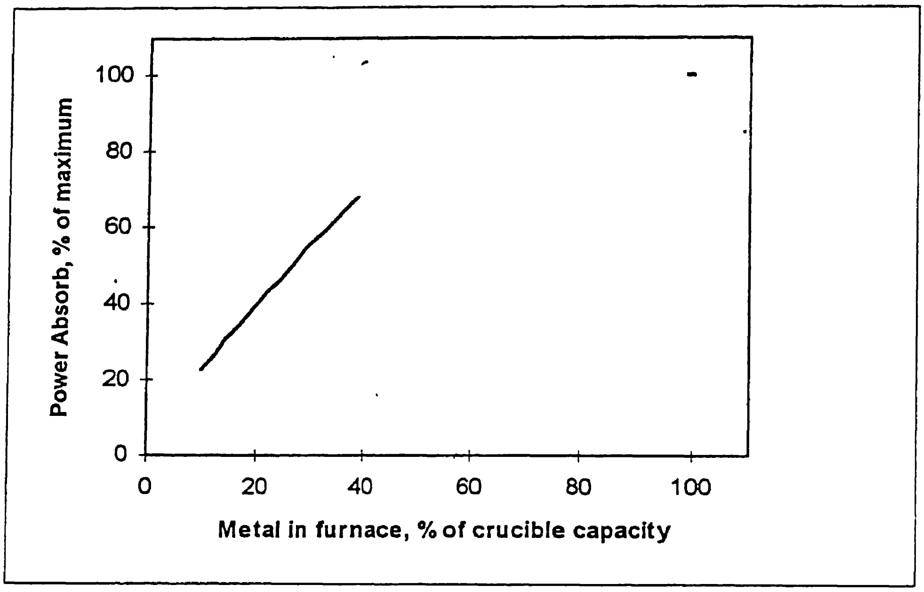
A General

1. Induction furnace current balancing is carried out manually. Auto balancing of currents is suggested for balanced loading of furnace transformer.
2. Panel meters for Furnace II & III needs to be calibrated, if necessary replaced for better monitoring of power usage.

B Induction Furnace II & III (Rodding Shop)

1. Optimum cycle time 1:30 min has to be maintained.
2. To know liquid metal temperature for pouring infrared thermometers can be used. By temperature measurement over-shooting can be avoided, extra amount of energy required for over shooting can be cut down.

3. Present ladle capacity is 0.8 tonnes. The quantity of slag formation during melting operation is around 10%. By providing one induction furnace of 5 - 6 ton and maintain heel two-third of volume, 5-7% energy savings is possible. The below graph gives the relation between power absorbed and metal held in crucible of a mains frequency coreless furnace.



For higher capacity furnace, surface heat losses are less compared with smaller furnace capacity.

For higher capacity induction furnace installation, detailed engineering has to be carried out.

8.0 CONCLUSION

The scope for conservation of energy at National Aluminium Co.Ltd. Smelter Plant, Carbon area has been studied and discussed in detail. There appears to be a good scope for reducing the energy consumption by implementation of various energy conservation opportunities discussed before.

The implementation of these recommendations calls for active involvement and co-operation from all the personnel in the department.

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APPENDICES

APPENDIX - 2/1

MONTHLY PRODUCTION AND ENERGY CONSUMPTION

A. ANODE PASTE PLANT

Month	Electricity kWh/Mt	HFO litre/Mt	Production Mt
April 96	73.41	10.58	7756
May 96	54.24	10.26	11466
June 96	52.47	10.41	11387
July 96	58.61	10.45	11167
August 96	54.77	10.41	11722
September 96	63.38	10.30	10008
October 96	60.99	10.68	11088
November 96	52.46	10.35	11810
December 96	68.49	10.52	9534
January 97	87.62	10.53	6416
February 97	57.90	10.45	9098
Total	60.63	10.44	111451

Appendix - 2/1 contd..

MONTHLY PRODUCTION AND ENERGY CONSUMPTION

B. BAKING OVEN

Month	Production (Mt) Nos. in brackets	Specific Consumption		
		Fuel oil Consumption litre/Mt	Power Consumption kWh/Mt	C.P.Coke kg/T
April 96	10158 (8727)	68.98	71.01	20.67
May 96	10037 (8630)	60.16	76.85	19.43
June 96	8903 (7655)	73.69	76.85	23.59
July 96	10163 (8731)	71.85	78.69	20.66
August 96	10219 (8779)	73.33	76.81	19.38
September 96	8493 (7315)	86.82	80.00	12.36
October 96	9965 (8613)	75.15	72.98	23.18
November 96	9255 (8090)	74.38	78.27	22.37
December 96	7772 (6752)	87.46	101.8	21.87
January 97	9558 (8052)	76.84	76.60	29.30
February 97	10070	79.49	62.70	35.15
Total	104592	74.86	76.94	22.53

Appendix - 2/1 contd..

MONTHLY PRODUCTION AND ENERGY CONSUMPTION

C. RODDING PLANT

Month	Production Nos.	Specific Consumption		
		C.I. Consumption kg/A	LDO litre/A	Power kWh/A
April 96	9102	18.7	0.81	50.54
May 96	9486	21.11	0.75	71.04
June 96	8948	17.91	0.75	49.95
July 96	9540	16.00	0.78	75.65
August 96	8989	21.66	0.69	55.33
September 96	8601	23.55	0.9	91.47
October 96	9239	27.55	0.85	86.21
November 96	9082	25.00	0.69	57.85
December 96	9863	17.11	0.70	57.78
January 97	8593	18.97	0.75	79.34
February 97	8232	21.27	0.80	71.53
Total	99675	20.50	0.77	67.90

Appen 3-1

APPENDIX - 3/1
Sht 1 of 5

MOTOR LOADING PARAMETERS

A. CARBON PLANT

Date : 26.2.97 to 28.2.97

SL. No.	APPLICATION / CONNECTED EQPT.	MOTOR						% LOADING
		RATED	MEASURED POWER PARAMETERS					
		kW	A	Cosϕ	V_L	kVA	kW	
	COKE FRACTIONATING							
1	M-7 Bucket Elevator	30.0	38.4	0.68	417.40	27.6	19.2	64.0
2	M-14 Impact Elevator	37.0	47.5	0.67	417.40	34.3	22.3	60.2
3	M-62 Dynamic Separator & Distance plate drive	37.0	19.3	0.38	413.90	14.0	5.2	14.1
4	M-63 Dynamic Separator Fan	37	60.7	0.88	412.20	42.8	39.7	107.2
5	M-113 Exhaust Fan	45.0	47.6	0.80	413.90	33.8	27.0	60.0
6	M-34 Vibrating Screen	11.0	10.2	0.76	417.40	7.2	5.7	52.1
7	M-97 Bucket Elevator	18.5	9.3	0.49	415.60	6.9	3.7	19.8
8	M-101 Pre-heating Screw	22.0	15.2	0.75	419.20	10.9	9.1	41.3
9	M-103 Mixer	132.0	91.0	0.98	417.40	62.1	53.7	40.6
		.. do..	43.0	0.76	417.40	32.4	25.9	19.5
10	MIB Roll Crusher	18.5	27.0	0.78	415.60	18.6	14.7	79.5
	VIBRO COMPACTING UNIT							
1	M-156 Mould No.1	55 UL	37.8	0.17	415.60	27.4	5.6	10.2
		L	70.0	0.74	415.60	50.7	34.3	62.4
2	M-157 Mould No.2	55 UL	39.5	0.17	415.60	28.5	6.7	12.1
			69.6	0.78	415.60	50.2	38.8	70.5
3	M-220 Hydraulic Power pack motors	90 UL	21.7	0.50	415.60	15.6	8.4	9.3
		L	123.2	0.88	415.60	88.7	80.1	89.0
	BOILER & HTF							
1	M-125A Melter Pump	11.0	6.6	0.57	419.00	4.8	2.6	23.5
2	M-125-B Melter Pump	11.0	Standby for above					
3	M-137-B Circulating Pump	55.0	65.8	0.91	420.90	48.0	44.8	81.5
4	M-140-B Piping Heating Pump	7.5	8.9	0.80	417.40	6.5	5.8	76.8
5	M-140-A Piping Heating Pump	7.5	Standby for above					
6	M-136-A Circulating Pump	55.0	Standby for M137-B					
7	M-141-A Heat Exchanger Pump	5.5	4.6	0.56	415.70	3.1	2.1	38.2
8	M-141-B Heat Exchanger Pump	5.5	Standby for above					

Appen 3-1

Appendix - 3/1 contd
Sht 2 of 5
Date : 26.2.97 to 28.2.97

SL. No.	APPLICATION / CONNECTED EQPT.	MOTOR RATED kW	MEASURED POWER PARAMETERS A	$\cos\phi$	V_L	kVA	kW	LOADING
9	M-143-A Preheatinng Screw Pump	11.0	11.4	0.79	419.20	8.3	7.1	64.6
10	M-143-B Preheatinng Screw Pump	7.5	Standby for above					
11	M-142-A Plug SCrew +	7.5	4.7	0.79	414.00	3.4	3.2	42.4
	Mix Heating Pump							
12	M-142-B Plug SCrew +	7.5	Standby for above					
	Mix Heating Pump							
13	M-136 Burner Fan	18.5	22.5	0.82	410.50	16.2	13.9	74.9
	GENERAL DEDUSTING							
14	M-115-dedusting Exhaust Fan	160.0	185.4	0.86	419.20	135.0	116.4	72.8
	BUTT FRACTIONATING							
1	M-36 Bucket Elevator	18.5	9.6	0.43	417.40	6.4	5.8	31.3
	PITCH HANDLING SYSTEM							
1	M-204 Belt Conveyor	15.0	10.4	0.43	408.80	8.2	3.7	24.6
2	M-209 Belt Conveyor	5.5	4.5	0.89	414.00	3.2	2.8	51.3
3	M-206 Hammer Crusher	45.0	24.5	0.44	410.50	15.34	7.1	15.8
	M-206 Hammer Crusher	45.0	36.8	0.66	410.50	18.2	8.0	17.7
	M-206 Hammer Crusher	45.0	66.9	0.67	410.50	46.9	31.4	69.9
4	M-126-B Melter Miner	37.0	38.2	0.63	414.00	27.2	17.4	47.1
5	M-126-A Melter Miner	37.0	Standby for above					
	ANODE HANDLING ZONE							
1	Cooling Tower Fan 10.3	9.0	7.5	0.42	415.00	5.4	2.8	31.0
2	Cooling Tower Fan 10.4	9.0	6.4	0.32	415.70	4.7	1.2	13.3
3	Cooling Tower Fan 10.1	9.0	Standby for above					
4	Cooling Tower Fan 10.2	9.0	Standby for above					
5	CW Pump 10.5	18.5	Standby for above 10.6 or 10.7					
6	CW Pump 10.6	18.5	30.0	0.82	419.00	22.1	18.3	98.9
7	CW Pump 10.7	18.5	21.2	0.25	419.00	24.7	12.5	67.5

Appen 3-1

Appendix - 3/1 contd

Sht 3 of 5

Date : 26.2.97 to 28.2.97

8	Cooling tunnel pump 11.1	37.0	68.6	0.80	419.00	49.4	42.0	113.5
9	Cooling tunnel pump 11.2	37.0	53.8	0.81	419.00	39.01	34.7	93.7
10	Cooling tunnel pump 11.3	37.0	Standby for above					
11	M-11.4 Steam Exhaust Fan	7.5	8.9	0.63	420.90	6.3	4.8	64.0
12	M-11.5 Steam Exhaust Fan	7.5	13.7	0.83	419.20	10.0	9.3	124.0
13	M- 057 Hot Well Pump	7.5	20.1	0.82	414.00	14.4	11.8	106.9
14	M058 Hot Well Pump	7.5	Standby for above					
	BAKED OVEN PLANT							
1	Air Blower No 1	30.0	27.5	0.78	426.00	20.5	15.8	52.6
2	Air Blower No 2	30.0	30.8	0.82	421.00	22.6	18.5	61.7
3	Air Blower No 3	30.0	27.0	0.85	426.00	19.4	17.9	59.6
4	Air Blower No 4	30.0	26.0	0.84	428.00	21.4	18.5	61.6
5	Air Blower No 6	30.0	Off Condition					
6	Air Blower No 8	30.0	29.0	0.77	416.00	22.5	17.5	58.3
7	Air Blower No 7	30.0	29.0	0.77	419.00	22.5	17.4	58.0
8	Air Blower No 9	30.0	37.0	0.84	423.00	28.4	23.4	78.0
9	FTA Crane -1	75.0	67.2	0.38	412.00	47.0	20.1	26.7
	Vacuum Pump Motors	75.0	59.2	0.27	410.00	39.2	14.5	19.4
		75.0	43.8	0.15	412.00	31.9	6.9	9.2
	RODDING SHOP							
1	M-76.1 Bath dedusting fan	125.0	75.4	0.78	417.00	53.0	43.4	34.7
2	M-329.1 Hyd. power pack	22.0	37.9	0.80	417.00	21.2	15.6	70.9
	hooking / unhooking							
3	M-449.3 Hyd. Power pack	22.0	40.5	0.79	417.00	27.7	23.2	105.5
	thimble press-1							
4	M-449.6 Hyd. Power pack	22.0	37.6	0.77	416.00	24.9	19.5	88.5
	thimble press-2							
5	M-459.3 Hyd. Power pack	22.0	38.6	0.77	417.00	24.1	18.8	85.2
	thimble press-3							

Appen 3-1

Appendix - 3/1 contd

Sht 4 of 5

Date : 26.2.97 to 28.2.97

6	M-449.1 Hyd. Power pack	15.0	26.3	0.73	421.00	18.8	15.0	100.2
	lifting table matting							
7	MP-1 CW Pump 1 F/C	7.5	14.3	0.82	410.00	9.4	8.6	114.4
8	MP-3 CW P-3 - F/C-3	7.5	14.6	0.87	405.00	10.3	9.0	119.6
9	Blower FAn-2 F/C -2	5.5	6.0	0.64	414.00	4.8	3.3	59.5
10	35 PM-54 HWP-1 F/C	11.0	14.4	0.93	409.00	10.8	9.3	84.8
11	M-35 PM-55 HWP-2 F/C	11.0	18.9	0.90	407.00	13.3	12.5	113.5
12	M-35 PM 56 HWP-3 F/C	11.0	16.4	0.82	405.00	8.7	16.5	58.6
13	M-58 Bath Conveyor	7.5	6.9	0.46	405.00	5.1	2.6	34.4
14	M-133 Bath Conveyor	18.5	15.5	0.63	405.00	10.8	6.8	36.4
15	M-60 Bath conveyor	11.0	14.5	0.73	405.00	10.3	7.8	71.2
16	M-14 Tripple deck vibrating screen	30.0	19.1	0.46	405.00	13.4	6.9	22.9
17	M06 Impact Crusher	90.0	138.0	0.76	404.00	98.9	74.8	83.1
18	Roots Blower (Bath)	30.0	22.0	0.74	405.00	15.8	9.6	31.9
19	M-008 Sec. JAW Crusher	30.0	18.0	0.35	414.00	19.3	8.4	27.8
20	M-469 Dedusting fan	132.0	187.6	0.83	412.00	130.8	81.6	61.8
21	Belt Conveyor M -66	15.0	9.7	0.37	416.00	7.0	2.9	19.6
22	M-165 Belt Conveyor	7.5	6.4	0.32	416.00	4.7	1.6	21.2
23	M-164 Butts SCrap Belt Conveyor	15.0	13.5	0.21	416.00	9.5	1.8	12.2
24	Single deck vibrating screen butt	7.5	6.9	0.4	416.00	5.0	2.9	39.2
25	M-65 Belt Conveyor (Butt)	7.5	7.0	0.33	416.00	5.1	2.6	34.0
26	ID Fan (additional Butt)	45.0	45.5	0.75	419.00	33.3	26.9	80.6
27	C-I Conveyor	15.0	14.0	0.36	405.00	10.4	4.3	28.6
28	C-II Conveyor	11.0	10.2	0.54	417.00	7.8	3.0	27.5
29	Hyd. Pump M-118.1	30.0	33.7	0.72	416.00	24.8	18.9	63.0
30	M-54 New dedusting fan	22.0	29.7	0.84	398.00	20.6	16.9	76.9
31	M-53 Bath Blower fan	90.0	104.9	0.85	405.00	73.2	63.3	70.3

Date : 26.2.97 to 28.2.97

MOTOR LOADING PARAMETER

B. LOADING PATTERN OF 66 kW SLIP RING MOTOR STACKING CRANE

Position	Duty	Volts 3 ϕ	Line Amps	P.F.	kVA 3 ϕ	kW 3 ϕ	Freq. Hz	Starting Amps
NO LOAD								
Up	High speed	417	80	0.84	56.7	38.0	51.6	130
Down	High speed	417	-	0.74	53.1	36.6	51.6	130
Up	Low speed	417	115	0.42 -0.62	83.1	48.6	51.6	130
LOAD								
Up	Low speed	423	103	0.84	71.7	62.1	51.8	170
Up	High speed	423	96	0.88	69.9	61.8	51.8	170
Down	Low speed	411	104	0.77	73.5	48.3	51.8	170
Down	High speed	411	65	0.85	60.0	47.1	51.8	170
	Max. Load recorded	411	125	0.80	84.9	73.2	-	-
	Instantaneous	411	120	0.88	-	75	-	-

REPLACEMENT OF STANDARD MOTORS BY HIGH EFFICIENCY MOTOR

Application : Air Blower - 001 (Bake Oven Plant)

Rated kW = 30 kW

Measured kW = 15.8 kW

Full load efficiency (Rated), η = 0.84

Derived data

Full load power $= \dfrac{\text{Rated kW}}{\text{Rated } \eta_{F.L.}}$

$= 35.71$ kW

Demand factor (D.F) $= \dfrac{\text{Measured kW}}{\text{Full load power}}$

$= 0.44$ kW

Operating efficiency $= 1 - \left[\dfrac{(1-\eta)(k_1 + (DF)^2 \times k_2)}{DF}\right] \times 100$

η = efficiency of motor
DF = demand factor
k_1 & k_2 are constants

$$= 1 - \left[\frac{(1-0.84)\,(0.38+(0.44)^2 \times 0.62)}{0.44} \right] \times 100$$

= 81.86%

Operating losses	= (1-η) x measured power
	= (1 - 0.8186) x 15.8
	= 2.86 kW

It is proposed to replace this motor by a high efficiency motor having a rated capacity of 30 kW.

Rated full load efficiency	= 92%
Operating efficiency of the motor with the present loading (using the same formulae)	= 91.32%
Operating losses	= (1 - 0.9132) x 15.8
	= 1.37 kW
Reduction in losses	= 2.86 - 1.37
	= 1.49 kW
Operating hours	= 8000/annum
Annual energy savings	= 11944 kWh

Appendix - 3/2 contd..
Sht 3 of 4

Annual cost savings	= Rs.10391/- @ Rs.0.87/kWh
Cost of implementation	= Rs.46,860/-
Simple payback period	= 4.51 years

Similar calculation for sizing of motors through computation has been carried out. Appendix - 3/2 represents the techno-economics for replacement of ordinary motors by high efficiency motors and sizing.

OPTIMUM SIZING AND USE OF ENERGY EFFICIENT MOTORS

CARBON PASTE PLANT

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW kW	FULL LOAD EFFICIENCY (η)	PROPOSED HIGH EFFICIENCY MOTOR kW	ANNUAL OPERATING HOURS	ANNUAL SAVINGS IN kWh	ANNUAL COST SAVINGS IN Rs.	INSTALLATION COST IN Rs.	PAY BACK PERIOD IN YEARS
1	M 113 Exhaust Fan	45.0	32.40	0 84	37 0	8000	23981	20863	72897	3.49
2	M 101 Pre heating screw	22.0	9.09	0.82	22 0	8000	10244	8912	33066	3 71
3	M 220 Hyd. motor (VCU)	90.0	80.10	0 85	90 0	8000	62170	54088	138512	2.56
4	M 136 Burner Fan	18.5	13.86	0.82	18.5	8000	11266	9802	30316	3.09
5	M 206 Hammer crusher	45.0	31.46	0.84	45.0	8000	23320	20289	72897	3.59
6	M 126 B Melter mixer	37.0	17.43	0 84	37 0	8000	15781	13729	58652	4.27
7	Air Blower - 001	30.0	15 78	0.84	30.0	8000	11944	10391	46860	4.51
8	Air Blower - 002	30.0	18 51	0.84	30.0	8000	12885	11210	46860	4 18
9	Air Blower - 003	30 0	17.88	0.84	30.0	8000	12655	11010	46860	4 26
10	Air Blower - 004	30.0	18.48	0 84	30 0	8000	12874	11200	46860	4.18
11	Air Blower - 007	30.0	17.40	0.84	30.0	8000	12484	10861	46860	4.31
12	Air Blower - 008	30 0	22.92	0.84	30.0	8000	14722	12808	46860	3 66
13	Air Blower - 009	30.0	23.40	0 84	30 0	8000	14945	13002	46860	3.60
14	M 76.1 Bath dedusting Fan	125.0	43 35	0.90	90.0	8000	29614	25764	138512	5.38
15	M 14 Tripple deck Vib.screen	30.0	11.83	0.84	30 0	8000	10848	9438	46860	4 97
16	M 06 Impact cruaher	90.0	74.76	0.85	90.0	8000	58524	50916	138512	2.72
17	M 53 Dedusting Fan	90.0	63.30	0.85	75.0	8000	46939	40837	119427	2 92
18	I D Fan (Addtl. Butt system)	45.0	26.85	0.84	37.0	8000	21979	19122	58652	3 07
							407175	**354242**	**1236323**	**3.07**

APPENDIX - 3/3

L .T. MOTORS RECOMMENDED FOR AUTO DELTA -STAR CONTROLLERS

CARBON PASTE PLANT

SL. No.	APPLICATION/ CONNECTED EQUIPMENT	PRESENT DRIVE kW	MEASURED kW	FULL LOAD EFFIC. η	FULL LOAD POWER	OPERT. LOSSES IN kW	SAVINGS IN LOSSES kW	OPERT. HOURS	ANNUAL SAVINGS IN kWH	COST SAVINGS IN Rs	INSTA--LATION COST Rs	PAY BACK PERIOD
1	M 7 Bucket Elevator	30.0	19.20	0.84	35.71	3.2	0.6	8000	5113	4448	21750	4.9
2	M 97 Bucket Elevator	18.5	3.66	0.82	22.56	1.6	0.3	8000	2575	2240	18750	8.4
3	M 36 Bucket Elevator	18.5	5.79	0.82	22.56	1.7	0.3	8000	2734	2379	21750	9.1
4	M 204 Belt Conveyor	15.0	3.70	0.82	18.29	1.3	0.3	8000	2136	1858	18750	10.1
5	M 133 Bath Conveyor	18.5	6.75	0.82	22.56	1.8	0.4	8000	2830	2462	18750	7.6
6	M 66 Belt Conveyor	15.0	2.94	0.82	18.29	1.3	0.3	8000	2086	1815	18750	10.3
7	M 164 Belt Conveyor	15.0	1.83	0.82	18.29	1.3	0.3	8000	2035	1770	18750	10.6
8	M 165 Belt Conveyor	7.5	1.59	0.82	9.15	0.7	0.1	8000	1050	914	18750	20.5
9	Conveyor C - I (Adtl Butt sys)	15.0	4.29	0.82	18.29	1.4	0.3	8000	2182	1898	18750	9.9
10	Conveyor C - II (Adtl.Butt sys.)	11.0	3.03	0.82	13.41	1.0	0.2	8000	1590	1384	18750	13.6
							TOTAL =		24331	21168	193500	9.1

INSTALLATION OF SOFT STARTER FOR VARIABLE LOADED MOTORS

Area : Rodding Shop

Application = M449.6 Hydraulic Thimble Press 2

Rating = 22 kW

Soft starter senses the motor load and accordingly controls the magnitude of input voltage to motor terminal in order to improve efficiency and reduce the losses.

The observations recorded along with the calculations are given below:

No load operation cycle	= 2000 hrs/annum
Measured power	= 5.6 kW
Average PF	= 0.45
Operating voltage	= 417
θ	$= \cos^{-1}(0.45)$
	$= 63.25^{0}$
V_{motor}	$= (\sqrt{2}\, V_{op})\,\sqrt{\tfrac{1}{2\pi}\{\theta-(\sin 2\theta/2)\}^{\pi}_{63}}$
	= 367 V
% reduction in voltage	= 12%

% reduction in losses	$= [1 - (1 - 0.12)^2]$
	= 22.4%
Operating losses (assuming 80% η for motor)	= 0.2 x 5.61 kW
	= 1.12 kW
Savings in losses in kW	= 1.12 x 0.244
	= 0.25 kW
Annual energy savings	= 0.25 x 2000
	= 500 kWh
Annual cost savings	= Rs.435/- @ 0.87/kWh
Load operation cycle	= 6000 hours/annum
Measured power	= 19.5 kW
Power factor	= 0.77
Operating voltage	= 416 V
θ	$= \cos^{-1} (0.77)$
	$= 39.64\,^{0}$
V_{motor}	$= (\sqrt{2}\, V_{op})\ \sqrt{\tfrac{1}{2\pi}\{\theta-(\sin 2\theta/2)\}^{\pi}_{39}}$
	= 402 V
% reduction in voltage	= 3%

% reduction in losses	$= [1 - (1 - 0.03)^2]$
	= 6.44%
Operating losses (assuming 80% η for motor)	= 0.2 x 19.5
	= 3.89 kW
Savings in losses in kW	= 3.89 x 0.0644
	= 0.25 kW
Annual energy savings	= 0.25 x 6000 (@ 16hrs/day for 365 days/year)
	= 1500 kWh
Annual cost savings	= Rs.1305/- @ Rs.0.87/kWh
Total annual energy savings	= 500 + 1500 kWh
	= 2000 kWh
Total annual cost savings	= Rs.435/- + Rs.1305/-
	= Rs.1740/-
Capacitor released	= 3 kVAr
Release of kVA demand per annum	= 60 kVA

Similar calculation for installation of energy savers for various motors has been carried out and is represented in Appendix - 3/4.

ENERGY SAVINGS BY USE OF ELECTRONIC ENERGY SAVERS

CARBON PASTE PLANT

Section - I

Sl. No.	APPLICATION / CONNECTED EQUIPMENT	RATED kW	VOLT -AGE	Pf Cos ϕ	SCR FIRING ANGLE	kW DRAWN	OPER- -TING Hrs/ DAY	MOTOR TERMI- -NAL VOLT	REDUC- -TION IN VOLT. %	REDUC- -TION IN LOSSES %	OPERAT- -ING AT 80% η IN kW	SAVING IN LOSSES IN kW
1	M 220 Hydraulic motor L	90.0	416	0.88	28	80.1	17.5	410	1	2.50	16.02	0.40
	- do - uL	90.0	416	0.5	60	8.4	4.5	373	10	19.60	1.68	0.33
2	M 329.1 Hyd. Hooking/unhooking	22.0	417	0.8	37	15.6	22	406	3	5.25	3.12	0.16
3	M 449.3 Hyd. Thimble Press 1	22.0	417	0.79	38	23.2	22	405	3	5.64	4.64	0.26
4	M 449.6 Hyd. Thimble Press 2	22.0	416	0.77	40	19.5	22	402	3	6.44	3.89	0.25
5	M 459.3 Hyd. Thimble Press 3	22.0	417	0.77	40	18.8	22	403	3	6.44	3.75	0.24
6	M 649.1 Hyd. lifting table matting	15.0	421	0.73	43	15.0	22	404	4	8.12	3.01	0.24
7	M 118.1 Hyd. Pump	30.0	416	0.72	44	18.9	22	398	4	8.56	3.78	0.32
	- do - uL	110.0	424	0.37	68	23.1	6.5	362	15	27.04	4.62	1.25

NOTE : Techno-economics of energy savings is represented in Appendix - 3/4.(section - II)

TATA ENERGY RESEARCH INSTITUTE
BANGALORE

ENERGY SAVINGS BY USE OF ELECTRONIC ENERGY SAVERS

CARBON PASTE PLANT

Section - I I

Sl. No.	APPLICATION / CONNECTED EQUIPMENT	RATED kW	Pf Cos ϕ	kW MEA-SUR-ED	REDUC-TION IN VOLT %	ANNUAL SAVINGS IN kWh	MONTHLY SAVINGS IN kVA	ANNUAL SAVINGS IN kVA	CAP. RELEASED IN kVAr	ANNUAL ENERGY SAVINGS IN Rs	INSTAL-ATION COST IN Rs
1	M 220 Hydraulic motor L	90 0	0.88	80.1	1	2556	25	300	11	2223	99875
	- do - uL	90.0	0.5	8 4	10	541				470	
2	M 329.1 Hyd. Hooking/unhooking	22.0	0.8	15.6	3	1316	5	60	3	1145	39975
3	M 449.3 Hyd. Thimble Press 1	22 0	0 79	23.2	3	2103	5	60	3	1829	39975
4	M 449.6 Hyd. Thimble Press 2	22.0	0 77	19.5	3	2012	5	60	3	1751	39975
5	M 459.3 Hyd. Thimble Press 3	22 0	0.77	18.8	3	1938	5	60	3	1686	39975
6	M 649.1 Hyd. lifting table matting	15.0	0.73	15.0	4	1961	4	48	2	1706	36225
7	M 118.1 Hyd. Pump	30.0	0.72	18.9	4	2597	8	96	5	2260	41850
					TOTAL =	15023	49	684	30	13070	337850

APPENDIX - 3/5

ELECTRONIC TEMPERATURE CONTROLLER FOR COOLING TOWER WATER SYSTEM OF GREEN ANODE COOLING

No. of fans	= 4 (2 Nos. in operation)
No. of CW pumps (18.5 kW each)	= 3 (2 Nos. in operation)

By installing electronic temperature controllers for two cooling tower fans and two CW pumps operation approximate reduction of 1000 operating hours per annum can be realised. (i.e. fans and pumps switch off during low ambient temperatures).

Power consumption of CW pump 10.6	= 18.3 kW
Power consumption of CW pump 10.7	= 12.5 kW
Power consumption of CT fan 10.3	= 2.8 kW
Power consumption of CT fan 10.4	= 1.2 kW
Total power consumption	= 34.8 kW
Annual energy savings	= 34.8 x 1000
	= 34800 kWh
Annual cost savings (@ Rs.0.87/kWh)	= Rs.30,276/-
Cost of implementation	= Rs.20,000/-
Simple payback period	= 0.66 years

APPENDIX - 3/6

Date : 26.2.97 to 28.2.97

H.T. MOTOR LOADING PARAMETERS

CARBON AREA

SL. No.	APPLICATION CONNECTED EQPT.	MOTOR MAKE	MOTOR RATED kW	MOTOR RPM / RPM	MOTOR RATED HZ	MEASURED 3-Ph. PARAMETERS Volts V	Amps A	Pf. Cosϕ	kVA	kW	kVAr	% LOAD-ING	REMARKS
	BALL MILL												
			400.0	988	50.1	6900	27 3	0.75	314.00	242.00		60.5	
			400.0			6840	27.0	0.71	319.00	227.00		56.8	
			400.0			6840	28 2	0.76	335.00	256.00		64.0	
			400.0		51	6900	26.4	0.77	315.00	243.00		60.8	
	I.D FAN-1		480.0		51	6960	32.4	0.71	399.00	282.00	282.00	58.8	
			480.0			7190	33.0	0.73	412.00	302.00		62.9	
			480.0		51 1	7170	36.0	0 78	448.00	347.00		72.3	
			480.0			7170	37 3	0.78	462.00	362.00	287.00	75.4	
			480.0		51 3	7170	37.6	0.79	469.00	370.00		77.1	Addln. damper ope
			480.0			7170	35.9	0.78	447.00	346.00		72.1	
	I.D FAN-3		480.0		51.9	7170	34.0	0.76	423.00	324.00	272.00	67.5	
			480.0		51.9	7170	34.0	0.77	423.00	326.00		67.9	
			480.0			7170	34.2	0.77	423.00	328.00	270.00	68.3	

APPENDIX - 4/1

OBSERVATIONS OF BAKE OVEN

A. BAKING OVEN DETAILS

No. of sections = 84

No. of supply air blowers = 8 (one standby)

No. of exhaust manifolds = 6 (four under use)

No. of ID fans = 3 (2 nos. in operation)

No. of firing zones = 4

B. FIRING NO. 4

Date : 01.03.1997

Section No.39

Sl. No.	After forced firing CO_2%	Before exhaust anode baking temp. °C	Draft mm Wc
1.	7.5	424	20
2.	8.5	441	17
3.	9.0	428	16
4.	9.0	445	13
5.	9.0	454	14
6.	7.0	449	16
7.	8.5	360	16

At exhaust manifold temperature = 1450 °C
Draft = 190 mm Wc

Appendix - 4/1 contd..

C. FIRING NO.3

Date : 03-03-1997

Sl. No.	% CO_2 After forced firing section -60	Section - 61	Section - 62	Before exhaust manifold temp. °C	Draft mm Wc
1.	8.0	4.5	3.0	397	15
2.	10.0	9.5	7.5	612	18
3.	7.5	7.5	4.5	536	16.5
4.	11.0	11.0	8.5	544	12.5
5.	11.0	10.5	8.5	600	15
6.	8.5	8.5	7.5	578	18
7.	8.5	7.5	4.0	517	22

At exhaust manifold = CO_2 % = 2 %
= Temp. = 225 °C
= Draft = 230 mmWc (vacuum)

D. FIRING NO.1

Date : 03-03-1997

Sl. No.	% CO_2 After forced firing section -19	Section - 20	Section - 21	Before exhaust manifold temp. °C	Draft mm Wc
1.	-	6.5	5.5	515	22
2.	7.5	7.5	5.5	453	16
3.	9.0	9.0	8.5	529	17
4.	8.0	8.0	6.5	506	-
5.	6.0	6.0	5.5	533	22
6.	7.5	7.0	6.0	514	19
7.	8.0	7.0	5.5	500	30

At exhaust manifold temperature = 185 °C

Appendix - 4/1 contd..

E. FIRING NO. 4

Date : 5.3.1997

Sl.No.	Section - 43 CO_2%	Section - 44 CO_2%	Draft
1.	6.0	4.5	-
2.	5.0	5.0	26
3.	6.0	6.0	18
4.	6.5	6.0	18.5
5.	7.5	7.0	24
6.	8.5	8.0	18.5
7.	8.5	6.5	24

Flue gas temperature = 215 °C

Draft = 170 mm Wc

CO_2% = 1%

APPENDIX - 4/2

COMBUSTION EFFICIENCY CALCULATIONS FOR FLUE WALLS

Combustion Efficiency **Flue Wall - 1**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of Fuel	HFO
	Fuel consumption rate /fire	250 litres/h
	Flue gas temperature	200 ° C
	CO_2 in flue gases	9.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	65 ° C
	Specific heat of fuel	0.5 kcal/kg °C
	Temperature of combustion air	1113 ° C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00
2)	Analysis	
A)	Stoichiometric Requirements - Per kg of fuel	
a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	64.30 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	22.65 kg
E)	Total flue gas quantity	23.65 kg

Appendix - 4/2 contd..

F)	Excess air quantity	8.86 kg
G)	Heat loss due to excess air	312.67 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.36 kg
I)	Dry flue gas quantity	22.24 kg

3) **HEAT BALANCE**

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	66.53
Sensible heat in fuel	16.50	0.11
Sensible heat in combustion air	5140.93	33.36
Total	15409.43	100.00
HEAT OUTPUTS		
Dry flue gas losses	920.35	5.97
Heat loss due to H_2 in fuel	682.86	4.43
Heat loss due to moisture in fuel	6.60	0.04
Heat loss due to moisture in air	29.22	0.19
Useful heat & Unaccounted losses	13770.40	89.36

Appendix - 4/2 contd..

Combustion Efficiency **Flue Wall - 2**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 °C
	CO_2 in flue gases	12.5 %
	Ambient air temperature	32 °C
	Wet bulb temperature	25 °C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	65 °C
	Specific heat of fuel	0.5 kcal/kg °C
	Temperature of combustion air	1053 °C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00
2)	Analysis	
A)	Stoichiometric Requirements - Per kg of fuel	
a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	24.87 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	17.21 kg
E)	Total flue gas quantity	18.21 kg

Appendix - 4/2 contd..

F)	Excess air quantity	3.43 kg
G)	Heat loss due to excess air	120.92 kcal

H) H_2O vapour in flue gas

a.	Due to H_2 in fuel	1.04 kg
b.	Due to H_2O in fuel	0.01 kg
c.	Due to H_2O in air	0.28 kg

I) Dry flue gas quantity 16.89 kg

3) HEAT BALANCE

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	73.44
Sensible heat in fuel	16.50	0.12
Sensible heat in combustion air	3690.25	26.44
Total	13958.75	100.00
HEAT OUTPUTS		
Dry flue gas losses	699.47	5.01
Heat loss due to H_2 in fuel	682.86	4.89
Heat loss due to moisture in fuel	6.60	0.05
Heat loss due to moisture in air	22.21	0.16
Useful heat & Unaccounted losses	12547.61	89.89

Appendix - 4/2 contd..

Combustion Efficiency **Flue Wall - 3**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of Fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 ° C
	CO_2 in flue gases	8.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	65 ° C
	Specific heat of fuel	0.5 kcal/kg °C
	Temperature of combustion air	1066 °C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2)	Analysis	
A)	Stoichiometric Requirements - Per kg of fuel	
a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	83.63 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	25.31 kg
E)	Total flue gas quantity	26.31 kg

Appendix - 4/2 contd..

F)	Excess air quantity	11.53 kg
G)	Heat loss due to excess air	406.67 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.40 kg
I)	Dry flue gas quantity	24.86 kg

3) HEAT BALANCE

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	65.03
Sensible heat in fuel	16.50	0.10
Sensible heat in combustion air	5495.93	34.86
Total	15764.43	100.00
HEAT OUTPUTS		
Dry flue gas losses	1028.63	6.52
Heat loss due to H_2 in fuel	682.86	4.33
Heat loss due to moisture in fuel	6.60	0.04
Heat loss due to moisture in air	32.66	0.21
Useful heat & Unaccounted losses	14013.69	88.89

Appendix - 4/2 contd..

Combustion Efficiency **Flue Wall - 4**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 ° C
	CO_2 in flue gases	10.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	58 ° C
	Specific heat of fuel	0.5 kcal/kg °C
	Temperature of combustion air	1064 ° C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2) Analysis

A) Stoichiometric Requirements - Per kg of fuel

a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	48.65 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	20.49 kg
E)	Total flue gas quantity	21.49 kg

Appendix - 4/2 contd..

F)	Excess air quantity	6.71 kg
G)	Heat loss due to excess air	236.58 kcal
H)	H_2O vapour in flue gas	
a.	Due to H_2 in fuel	1.04 kg
b.	Due to H_2O in fuel	0.01 kg
c.	Due to H_2O in air	0.33 kg
I)	Dry flue gas quantity	20.12 kg

3) HEAT BALANCE

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	69.72
Sensible heat in fuel	13.00	0.09
Sensible heat in combustion air	4440.48	30.20
Total	14705.48	100.00
HEAT OUTPUTS		
Dry flue gas losses	832.70	5.66
Heat loss due to H_2 in fuel	682.86	4.64
Heat loss due to moisture in fuel	6.60	0.04
Heat loss due to moisture in air	26.44	0.18
Useful heat & Unaccounted losses	13156.89	89.47

Appendix - 4/2 contd..

Combustion Efficiency Flue Wall - 5

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 ° C
	CO_2 in flue gases	9.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	58 ° C
	Specific heat of fuel	0.5 kcal/kg ° C
	Temperature of combustion air	1072 ° C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2) Analysis

A) Stoichiometric Requirements - Per kg of fuel

a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	64.30 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	22.65 kg
E)	Total flue gas quantity	23.65 kg

Appendix - 4/2 contd..

F)	Excess air quantity	8.86 kg
G)	Heat loss due to excess air	312.67 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.36 kg
I)	Dry flue gas quantity	22.24 kg

3) **HEAT BALANCE**

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	67.40
Sensible heat in fuel	13.00	0.09
Sensible heat in combustion air	4945.95	32.52
Total	15210.95	100.00
HEAT OUTPUTS		
Dry flue gas losses	920.35	6.05
Heat loss due to H_2 in fuel	682.86	4.49
Heat loss due to moisture in fuel	6.60	0.04
Heat loss due to moisture in air	29.22	0.19
Useful heat & Unaccounted losses	13571.92	89.23

Appendix - 4/2 contd..

Combustion Efficiency **Flue Wall - 6**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of Fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 ° C
	CO_2 In flue gases	11.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	65 ° C
	Specific heat of fuel	0.5 kcal/kg ° C
	Temperature of combustion air	1110 °C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2) Analysis

A) Stoichiometric Requirements - Per kg of fuel

a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	35.72 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	18.71 kg
E)	Total flue gas quantity	19.71 kg

Appendix - 4/2 contd..

F)	Excess air quantity	4.92 kg
G)	Heat loss due to excess air	173.72 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.30 kg
I)	Dry flue gas quantity	18.36 kg

3) **HEAT BALANCE**

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	70.69
Sensible heat in fuel	16.50	0.11
Sensible heat in combustion air	4235.07	29.20
Total	14503.57	100.00
HEAT OUTPUTS		
Dry flue gas losses	760.29	5.24
Heat loss due to H_2 in fuel	682.86	4.71
Heat loss due to moisture in fuel	6.60	0.05
Heat loss due to moisture in air	24.14	0.17
Useful heat & Unaccounted losses	13029.68	89.84

Appendix - 4/2 contd..

Combustion Efficiency **Flue Wall - 7**

	Basis	Per kg of fuel
	Procedure	BIS 8753
1)	Data	
	Type of fuel	HFO
	Fuel consumption rate per fire	250 litres/h
	Flue gas temperature	200 °C
	CO_2 in flue gases	8.5 %
	Ambient air temperature	32 °C
	Wet bulb temperature	25 °C
	Moisture content in air	0.016 kg/kg of air
	Fuel calorific value	10252 kcal/kg
	Fuel input temperature	65 °C
	Specific heat of fuel	0.5 kcal/kg °C
	Temperature of combustion air	1079 °C
	Composition of fuel	
	Carbon %	84.00
	Hydrozen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2) Analysis

A) Stoichiometric Requirements - Per kg of fuel

a.	Oxygen requirement	3.198 kg
b.	Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	83.63 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	25.31 kg
E)	Total flue gas quantity	26.31 kg

Appendix - 4/2 contd..

F)	Excess air quantity	11.53 kg
G)	Heat loss due to excess air	406.67 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.40 kg
I)	Dry flue gas quantity	24.86 kg

3) **HEAT BALANCE**

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	64.75
Sensible heat in fuel	16.50	0.10
Sensible heat in combustion air	5565.03	35.15
Total	15833.53	100.00
HEAT OUTPUTS		
Dry flue gas losses	1028.63	6.50
Heat loss due to H_2 in fuel	682.86	4.31
Heat loss due to moisture in fuel	6.60	0.04
Heat loss due to moisture in air	32.66	0.21
Useful heat & Unaccounted losses	14082.79	88.94

QUANTIFICATION OF AIR INFILTRATION

Fire No.3

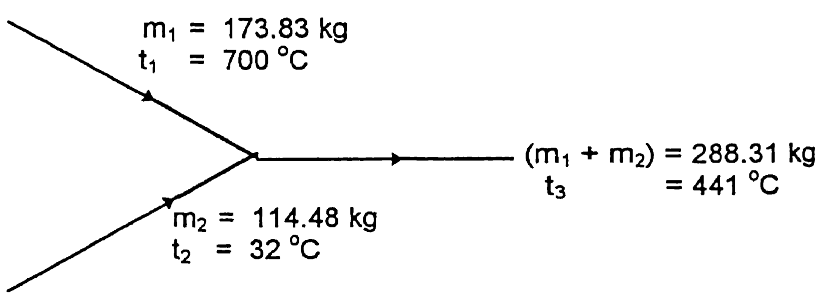
Flue Wall No.	Measured CO_2%			Corresponding Excess Air %			Corresponding Excess Air in kg			Flue Gas Quantity in kg	
	Section 60	Section 61	Section 62	Section 60	Section 61	Section 62	Section 60	Section 61	Section 62	Section 60	Section 62
1.	8.0	4.5	3.0	95.10	246.85	420.28	13.11	34.03	57.93	27.89	72.71
2.	10.0	9.5	7.5	56.08	64.3	108.11	7.73	8.86	14.90	22.51	29.69
3.	7.5	7.5	4.5	108.11	108.11	246.85	14.90	14.90	34.03	29.69	48.81
4.	11.0	11.0	8.5	41.89	41.89	83.63	5.77	5.77	11.53	20.56	26.31
5.	11.0	10.5	8.5	41.89	48.65	83.63	5.77	6.71	11.53	20.56	26.31
6.	8.5	8.5	7.5	83.63	83.63	108.11	11.53	11.53	14.90	26.31	29.69
7.	8.5	7.5	4.0	83.63	108.11	290.21	11.53	14.90	40.00	26.31	54.78
TOTAL							**70.34**	**96.7**	**184.82**	**173.83**	**288.3**

Quantity difference in section 60 and 62 is air infiltration = 114.48 kg

APPENDIX - 4/4

TEMPERATURE DROP DUE TO AIR INFILTRATION

Flue gas quantity after burning (m_1)	=	173.83 kg
Average flue gas temperature at 3rd preheating section (t_1)	=	700 °C
Air infiltration quantity (m_2)	=	114.48 kg
Ambient air temperature (t_2)	=	32 °C
Flue gas quantity at first preheating section ($m_1 + m_2$)	=	288.31 kg
Temperature of flue gas after air infiltration (t_3)	=	441 ° C
Specific heat of flue gas at 700 °C	=	0.296 kcal/kg°C
Specific heat of air at 32 °C	=	0.24 kcal/kg°C



Temperature drop due to air ingress	=	700 - 441
	=	259 °C

APPENDIX - 5/1

SPECIFICATIONS OF THERMIC FLUID HEATER

Equipment	= Heat Transfer Fluid and Liquid Pitch System
Make	= Fives -Cail - Babcock
Consumption rate	= Heavy fuel oil No.2 : 375 kg
Power consumption (Electric preheater for fuel)	= 30 kW
Burner type	= RPDFS 30 Duobloc with modulating control
DP boiler burner	= 200 mm CE
Flue gas temperature	= 300 °C
Combustible	= Heavy fuel oil N - 2 - 6 - °C - 2 bars
Power supply	= Voltage 415 V - 50 Hz Trip phase
Control supply	= Voltage 240 V - 50 Hz
Blower	
Flow rate	= 4900 m^3/h
Static pressure	= 400 mm Wc
Orientation	= Horizontal outlet to bottom in left seen from driven end
Fuel supply pressure	= 20 to 40 bar
Fuel viscosity under	= 3 °E

APPENDIX - 5/2

OBSERVATIONS DURING COMBUSTION EFFICIENCY TRIAL

Time	9.00	10.00	11.00
HTF inlet temp. (°C)	224	225	225
HTF outlet temp. (°C)	229	228	229
Flue gas temp. (°C)	265	259	259
Preheated oil temp. (°C)	65	65	65
CO_2%	4.5	-	4.5

APPENDIX - 5/3

COMBUSTION EFFICIENCY CALCULATION
THERMIC FLUID HEATER

	Basis	***Per kg of Fuel***
	Procedure	***BIS 8753***
1)	DATA	
	Type of Fuel	HFO
	Fuel consumption rate	120 l/h
	Flue gas temperature	259 ° C
	CO_2 in flue gases	4.5 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in Air	0.016 kg/kg of air
	Fuel calorific Value	10252 kcal/kg
	Fuel input temperature	65 ° C
	Specific heat of fuel	0.5 kcal/kg ° C
	Temperature of combustion air	150 ° C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00
2)	ANALYSIS	
A)	Stoichiometric Requirements - Per kg of fuel	
	a. Oxygen requirement	3.198 kg
	b. Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	246.85 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	47.81 kg
E)	Total flue gas quantity	48.81 kg
F)	Excess air quantity	34.03 kg

G) Heat loss due to excess air — 1621.98 kcal

H) H_2O vapour in flue gas

a. Due to H_2 in fuel — 1.04 kg

b. Due to H_2O in fuel — 0.01 kg

c. Due to H_2O in air — 0.76 kg

I) Dry flue gas quantity — 47.00 kg

3) HEAT BALANCE

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	89.51
Sensible heat in fuel	16.50	0.14
Sensible heat in combustion air	1184.70	10.34
Total	11453.20	100.00
HEAT OUTPUTS		
Dry flue gas losses	2625.32	22.92
Heat loss due to H_2 in fuel	710.33	6.20
Heat loss due to moisture in fuel	6.86	0.06
Heat loss due to moisture in air	83.35	0.73
Useful heat & Unaccounted losses	8027.35	70.09

APPENDIX - 5/4

COMBUSTION EFFICIENCY CALCULATION AFTER EXCESS AIR CONTROL

	Basis	***Per kg of Fuel***
	Procedure	***BIS 8753***
1)	DATA	
	Type of Fuel	HFO
	Fuel consumption rate	120 l/h
	Flue gas temperature	259 ° C
	CO_2 in flue gases	13 %
	Ambient air temperature	32 ° C
	Wet bulb temperature	25 ° C
	Moisture content in Air	0.016 kg/kg of air
	Fuel calorific Value	10252 kcal/kg
	Fuel input temperature	100 ° C
	Specific heat of fuel	0.5 kcal/kg ° C
	Temperature of combustion air	150 ° C
	Composition of fuel	
	Carbon %	84.00
	Hydrogen %	11.50
	Sulphur %	3.50
	Moisture %	1.00

2) ANALYSIS

A) Stoichiometric Requirements - Per kg of fuel

	a. Oxygen requirement	3.198 kg
	b. Combustion air requirement	13.784 kg
B)	Excess air in flue gas %	20.06 %
C)	Combustion air requirement	13.78 kg
D)	Total air supplied	16.55 kg

Appendix - 5/4 contd..

E)	Total flue gas quantity	17.55 kg
F)	Excess air quantity	2.77 kg
G)	Heat loss due to excess air	131.84 kcal
H)	H_2O vapour in flue gas	
	a. Due to H_2 in fuel	1.04 kg
	b. Due to H_2O in fuel	0.01 kg
	c. Due to H_2O in air	0.26 kg
I)	Dry flue gas quantity	16.24 kg

3) HEAT BALANCE

Particulars	kcal/kg	Percentage
HEAT INPUTS		
Through heat value of fuel	10252.00	95.85
Sensible heat in fuel	34.00	0.32
Sensible heat in combustion air	410.09	3.83
Total	10696.09	100.00
HEAT OUTPUTS		
Dry flue gas losses	908.76	8.50
Heat loss due to H_2 in fuel	710.33	6.64
Heat loss due to moisture in fuel	6.86	0.06
Heat loss due to moisture in air	28.85	0.27
Useful heat & Unaccounted losses	9041.28	84.53

APPENDIX - 5/5

ENERGY SAVINGS AFTER INSTALLATION OF MODULATOR SYSTEM

Present combustion efficiency	= 70.09%
Improvement in combustion efficiency after installation of modulator to control excess air	= 84.53%
% of improvement over existing combustion efficiency	= 14.44
Average fuel consumption	= 20 kL per week
No. of weeks	= 52
Annual fuel savings	= 149.76 kL
80% of the above savings can be realisable	
Expected fuel savings	= 120 kL
Cost of HFO	= Rs.7460/- per kL
Cost savings	= 120 x 7460
	= Rs.8,95,200/y
Investment required	= Rs.3.0 lakh
Simple payback period	= 0.33 years

APPENDIX - 5/6

OBSERVATIONS OF HTF DISTRIBUTION SYSTEM

Sl. No.	Temperatures of HTF at Distribution Pumps	Set Temperatures °C	Observed Pressures kg/cm^2g
1.	Storage tank 128A	150	-
2.	Preheating screw U143 (Stop)	150	2.25
	(Running)	175	2.25
3.	Liquid storage 139	200	-
4.	Mixer U142	150	1.8
5.	Pitch piping U140	190	5.0
6.	U141	165	-

Sl. No.	Temperatures of HTF at Distribution Pumps	Set Temperatures °C	Observed temperature °C
1.	Preheating screw (TIC 8716)	185 ± 5	175 (Running) 150 (Stop)
2.	Mixer (TIC 865)	150 ± 2	150
3.	Piping temperature (TIC 879)	190 ± 5	190
4.	Pitch temperature (Volumetric pump outlet)	150 ± 10	-

APPENDIX - 5/7

OBSERVED HTF DISTRIBUTION LINE SURFACE TEMPERATURES

Ambient temperature = 28 °C

Pump No.	Distribution Line	Measured Surface Temp. °C
139	Supply	31
	Return	29
140	Supply	30
	Return	29
141	Supply	30
	Return	29
Main Pump	Supply	35
	Return	35
125A	Supply	28
	Return	34
142A	Supply	34
	Return	34
	Primary supply	37
	Return	34
143A	Supply	38
	Return	36
	Primary supply	35
	Return	35

APPENDIX - 6/1

DESIGN PARAMETERS OF FANS

Area	Quantity (m^3/s)	Total static pressure (Pa)	Max. Temp. (oC)	Outlet velocity (m/s)	Motor Rating kW	Fan η (%)
Bake Oven						
Induced draft	50.70	5003	350	32.3	480	56.5
Forced draft fans (Blowers)	9.86	1650	50	12.83	30	85.6
Anode Paste Plant						
General dedusting fan (U115)	16.67	4756	47	19.5	160	67
Ball mill vent fan (U113)	5.56	4021	80	17.2	45	71

APPENDIX - 6/2

MEASURED PARAMETERS FOR ID FANS IN BAKE OVEN

Date: 4.3.97

Measured Parameters	Unit	ID Fans (Common Sample Point)
Density	kg/m^3	0.9525
Temperature	°C	89
Static Pressure (Suction side)	mm Wg	
i. At sample point		- 255
ii. Near fan		- 300
Static Pressure (Delivery side)	mm Wg	+.10
Dynamic (Velocity) Pressure, rms value	mm Wg	30.59
Duct Diameter	m	2.55
Velocity	m/s	25.10
Quantity	m^3/h	4,43,578
	Nm^3/h	3,26,260
Speed	%	100
Damper opening	%	100
Theoretical power	kW	375
Measured power	kW	688

APPENDIX - 6/3

MEASURED PARAMETERS FOR FORCED DRAFT FANS (BLOWERS) IN BAKE OVEN

Date : 4.3.97

Blower No.	Application	Velocity (m/s)	Area (m^2)	Flow Quantity (m^3/h)	Flow Quantity (Nm^3/h)	Outlet Damper Opening (%)
420701	Combustion air	3.372	1.9306	23435	21115	50
420709	Cooling baked anode	6.021	1.9306	41848	37705	100
420702	Combustion air	3.969	1.9306	27586	24855	50
420706	Cooling baked anode	5.439	1.9306	37799	34056	100
420703	Combustion air	3.789	1.9306	26337	23729	50
	Cooling baked anode	5.670	1.9306	39407	35505	100
420707	Combustion air	3.538	1.9306	24590	22155	50
420708	Cooling baked anode	5.898	1.9306	40990	36932	100
TOTAL				**261992**	**236052**	-

All blowers are operated at 100% speed.

APPENDIX - 6/4

MEASURED PARAMETERS FOR DEDUSTING AND VENTING FANS IN ANODE PASTE PLANT

Date : 12.3.97

Measured Parameters	Units	General Dedusting Fan U -115	Ball Mill Vent Fan U - 113 *
Density	kg/m^3	1.147	1.147
Temperature	°C	34	34
Static Pressure (Suction side)	mm Wg	-	-
Delivery side		+ 5	+ 5
Dynamic (Velocity) Pressure, rms value	mm Wg	17.50	8.5
Duct Diameter	m	1	0.75
Velocity	m/s	17.30	12.06
Quantity	m^3/h	48,915	19.181
	Nm^3/h	43,492	17,054
Speed	%	100	100
Damper opening	%	100	100

* Fan was run for taking measurements.

ARRESTING AIR INFILTRATION IN ID FANS CIRCUIT IN BAKE OVEN

The flow measurements was taken at a common sample point for ID fans which are in operation.

1. As per the measurement the exhaust flue gas flow from bake oven is 4,43,578 m^3/h or 3,26,260 Nm^3/h.

2. The design value of exhaust flue gas from bake oven is 1,60,000 Nm^3/h.

3. The difference in flow quantity between measured and design value (1,66,260 Nm^3/h) accounts for air infiltration in the circuit.

4. By arresting 30% of this air infiltration the quantity to be handled by ID fans get reduced to 2,76,382 Nm^3/h or 3,75,764 m^3/h.

5. The actual power required for this flow, for measured total static pressure of 310 mm Wg and considering fans and motor efficiency is :

$$\text{Power requirement, kW} = \frac{Q \times TP \times g}{3600 \times 1000 \times \eta_{fan} \times \eta_{motor}}$$

Where Q	=	Quantity of flue gas in m^3/h	= 3,75,764 m^3/h
TP	=	Total static pressure in mm Wg	= 310 mm Wg
η_{fan}	=	Efficiency of fan	= 57%
η_{motor}	=	Efficiency of motor	= 92%

$$\text{Power requirement, kW} = \frac{375764 \times 310 \times 9.81}{3600 \times 1000 \times 0.57 \times 0.92}$$

$$= 605 \text{ kW}$$

6. The present power consumption by 2 fans is 688 kW. So, by arresting 30% of air infiltration, the power savings/hour :

	= 688 - 605 kW
	= 83 kW
Annual energy savings (@ 8000 hours/annum)	= 6,64,000
	= 6.64 lakh kWh
Annual cost savings (@ 0.87 paise / unit)	= 6.64 x 0.87
	= Rs.5.78 lakh

7.

Annual cost savings	= Rs.5.78 lakh
Cost of implementation	= Marginal
Simple payback period	= Immediate

APPENDIX - 6/6

COMPRESSED AIR (FROM MAIN COMPRESSORS) LEAKAGE POINTS

CARBON AREA

Date : 22.2.97

Sl. No.	Area	Orifice dia (mm)	Corresponding Qty. (m^3/min)
PIN REPAIR SHOP			
1.	Branch pipeline	1 No. ⇒ 16	14.00
2.	Anode conveyor	1 No. ⇒ 10	5.5
ANODE PASTE PLANT			
1.	35 m ht. - pipeline	1 No. ⇒ 4	0.85
2.	29 m ht. Branch pipeline	1 No. ⇒ 1	0.05
3.	24 m ht. Dust collector	1 No. ⇒ 1	0.05
4.	19 m ht. Dust collector chute hose	1 No. ⇒ 4	0.85
5.	15 m ht coke unloading chute	1 No. ⇒ 16	14.00
6.	10 m ht. Near crusher main pipeline	1 No. ⇒ 6	2.00
7.	Pipeline joint leakage (Near control room)	1 No. ⇒ 2	0.22
8.	Near Ball mill	1 No. ⇒ 6	2.00
9.	Ground floor branch pipeline	1 No. ⇒ 1	0.05
10	Ground floor pipeline (Near M-25-4 Screw conv)	1 No. ⇒ 4	0.85
11.	Ground floor Big blaster m/c	1 No. ⇒ 4 3 Nos.⇒ 1	0.85 0.15
BUTT AND BATH AREA			
1.	Branch pipeline	1 No. ⇒ 12	8.00
BAKE OVEN			
1.	Branch line gate valve	1 No. ⇒ 16	14.00
2.	Branch line gate valves	8 Nos. ⇒ 1	0.40
3.	Branch line gate valves	2 Nos. ⇒ 2	0.44
4.	Pipe line damage	1 No. ⇒ 2	0.22
	Total		**64.48**

APPENDIX -7/1

POWER MEASUREMENT OF INDUCTION FURNACE - 2 HEAT CYCLE

TIME	kV	I	Hz	kV_R	kV_Y	kV_B	I_R	I_Y	I_B	kW	kVA	kVAr	Cos ϕ	kW_R	kW_Y	kW_B	kWh	kVArh	kVA(Peak)	kW(Peak)
16.47	11.2	0.00	50.3	6.36	6.58	6.45	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0
16.51	11.2	9.28	50.0	6.36	6.58	6.46	18.80	5.28	4.02	170.0	180.0	57.8	0.95	112.0	33.1	25.4	10.0	3.0	424	409
16.55	11.2	10.20	49.5	6.34	6.56	6.44	21.50	5.49	3.97	180.0	197.0	81.6	0.91	123.0	31.4	24.9	22.0	7.0	424	409
17.02	11.1	23.40	49.9	6.33	6.55	6.42	47.90	14.80	8.27	435.0	451.0	120.0	0.96	297.0	86.8	51.2	61.0	21.0	451	435
17.06	11.1	21.80	50.2	6.31	6.53	6.4	43.10	14.40	8.22	405.0	418.0	106.0	0.97	265.0	89.0	51.0	89.0	29.0	451	435
17.10	11.1	22.70	49.9	6.31	6.52	6.4	46.20	14.40	8.25	413.0	437.0	144.0	0.94	277.0	84.5	51.0	116.0	37.0	451	435
17.17	11.1	28.40	49.0	6.29	6.51	6.39	62.40	16.80	8.20	463.0	545.0	288.0	0.85	345.0	68.0	50.0	161.0	58.0	451	435
17.21	11.1	0.50	49.0	6.32	6.52	6.4	1.08	0.25	0.21	2.1	9.7	9.5	0.21	0.7	0.6	0.7	187.0	74.0	451	435
17.25	11.2	0.50	49.5	6.38	6.59	6.47	1.07	0.24	0.22	2.4	9.7	9.4	0.25	1.1	0.6	0.7	187.0	75.0	451	435
17.32	11.2	22.00	49.7	6.36	6.57	6.44	41.90	17.20	7.28	419.0	426.0	76.1	0.98	264.0	110.0	45.0	192.0	77.0	545	463
17.36	11.1	28.00	49.4	6.32	6.54	6.42	57.60	19.50	8.05	485.0	540.0	238.0	0.90	334.0	102.0	48.7	224.0	91.0	545	463
17.40	11.2	31.60	49.2	6.36	6.57	6.46	61.10	28.40	8.11	604.0	613.0	106.0	0.99	390.0	164.0	49.4	256.0	108.0	545	463
17.47	11.2	29.50	49.4	6.33	6.55	6.43	60.50	21.50	7.92	500.0	570.0	273.0	0.88	346.0	105.0	48.5	316.0	139.0	545	463
17.51	11.1	28.80	49.5	6.33	6.54	6.43	58.70	20.80	7.98	492.0	555.0	256.0	0.89	338.0	106.0	48.6	350.0	157.0	545	463
17.55	11.1	28.80	49.7	6.33	6.54	6.41	50.10	27.00	9.66	549.0	555.0	83.3	0.99	315.0	174.0	59.4	384.0	165.0	545	463
18.02	11.2	30.10	49.4	6.34	6.57	6.44	53.90	27.30	9.65	562.0	583.0	156.0	0.96	331.0	171.0	59.5	457.0	181.0	613	604
18.06	11.2	28.90	49.4	6.34	6.56	6.44	55.20	22.40	9.57	536.0	558.0	154.0	0.96	338.0	139.0	58.9	480.0	188.0	613	604
18.10	11.1	29.30	49.4	6.33	6.55	6.42	53.70	25.10	9.56	547.0	566.0	144.0	0.97	330.0	158.0	58.8	516.0	198.0	613	604
18.17	11.2	29.90	49.3	6.33	6.55	6.43	53.60	26.90	9.55	554.0	577.0	158.0	0.96	328.0	168.0	58.6	572.0	211.0	613	604
18.21	11.2	0.53	49.3	6.38	6.59	6.47	1.11	0.34	0.19	2.4	10.5	10.2	0.23	0.8	0.9	0.6	599.0	219.0	613	604
18.25	11.2	30.50	49.3	6.37	6.59	6.47	59.90	22.60	9.61	556.0	592.0	205.0	0.94	361.0	135.0	59.2	604.0	222.0	613	604
18.32	11.2	26.00	49.1	6.34	6.55	6.44	50.80	20.00	7.95	470.0	503.0	178.0	0.94	304.0	118.0	48.7	660.0	242.0	613	604
18.36	11.2	26.20	49.1	6.34	6.55	6.43	50.50	20.70	7.94	471.0	506.0	184.0	0.93	301.0	122.0	48.7	692.0	254.0	613	604
18.40	11.2	30.60	49.1	6.34	6.56	6.44	60.80	22.40	9.50	548.0	593.0	226.0	0.93	359.0	131.0	58.2	726.0	268.0	613	604
18.47	11.3	0.55	49.2	6.42	6.63	6.51	1.18	0.30	0.20	2.2	10.8	10.5	0.20	0.8	0.7	0.7	769.0	285.0	613	604

POWER MEASUREMENT OF INDUCTION FURNACE - 3 HEAT CYCLE

TIME	kV	I	Hz	kV_R	kV_Y	kV_B	I_R	I_Y	I_B	kW	kVA	kVAr	Cos ϕ	kW_R	kW_Y	kW_B	kWh	kVArh	kVA(Peak)	kW(Peak)
10:55	11.4	0.1	51.3	6.49	6.69	6.52	0.2	0.2	0.0	1.6	2.5	1.9	0.63	1.0	0.6	0.0	0.0	0.0	0.0	0.0
11:2	11.5	16.7	51.5	6.53	6.74	6.56	24.6	17.0	9.6	323.0	331.0	72.6	0.98	158.0	103.0	62.4	19.0	4.0	389.0	385.0
11:6	11.4	16.2	51.4	6.52	6.72	6.56	23.6	16.4	9.6	313.0	320.0	67.5	0.98	152.0	98.4	62.2	40.0	8.0	389.0	385.0
11:10	11.4	16.8	50.9	6.48	6.69	6.52	26.4	16.3	9.4	313.0	331.0	106.0	0.95	165.0	87.1	61.3	61.0	14.0	389.0	385.0
11:17	11.4	17.3	50.9	6.48	6.68	6.51	24.0	16.9	11.4	335.0	340.0	57.1	0.99	153.0	108.0	73.8	87.0	20.0	389.0	385.0
11:21	11.4	19.7	50.9	6.49	6.69	6.52	27.9	20.3	11.6	383.0	389.0	66.6	0.99	180.0	128.0	75.3	108.0	24.0	389.0	385.0
11:25	11.4	19.5	50.9	6.48	6.69	6.51	27.8	19.8	11.5	376.0	384.0	78.1	0.98	178.0	123.0	75.0	134.0	29.0	389.0	385.0
11:32	11.4	18.6	51.1	6.53	6.72	6.55	25.2	19.3	11.7	368.0	369.0	31.7	1.00	164.0	127.0	76.5	178.0	36.0	389.0	385.0
11:36	11.5	18.8	51.2	6.54	6.74	6.57	25.6	19.5	11.7	372.0	374.0	42.4	0.99	167.0	128.0	76.7	203.0	37.0	389.0	385.0
11:40	11.4	18.3	51.4	6.52	6.72	6.56	23.9	19.5	11.7	363.0	363.0	10.0	1.00	156.0	130.0	76.7	227.0	39.0	389.0	385.0
11:47	11.5	18.5	51.6	6.57	6.77	6.6	27.7	17.3	11.6	360.0	369.0	81.1	0.98	177.0	106.0	76.4	269.0	41.0	389.0	385.0
11:51	11.4	19.1	51.3	6.48	6.68	6.52	30.0	18.1	11.4	356.0	377.0	122.0	0.95	187.0	95.9	74.0	293.0	47.0	389.0	385.0
11:55	11.4	19.4	51.2	6.47	6.68	6.51	31.3	18.2	11.3	353.0	382.0	146.0	0.92	191.0	88.8	73.5	317.0	57.0	389.0	385.0
12:2	11.4	18.3	51.3	6.5	6.7	6.53	25.1	18.6	11.7	360.0	362.0	36.5	1.00	162.0	122.0	75.6	363.0	72.0	389.0	385.0
12:6	11.4	18.2	51.5	6.52	6.72	6.55	24.3	18.9	11.7	360.0	360.0	11.2	1.00	158.0	126.0	76.3	387.0	74.0	389.0	385.0
12:10	11.5	18.0	51.7	6.53	6.74	6.56	22.7	19.5	11.8	357.0	357.0	808.1	1.00	148.0	131.0	77.0	411.0	74.0	389.0	385.0
12:17	11.4	17.8	51.6	6.53	6.73	6.56	22.5	19.1	11.8	352.0	352.0	3.7	1.00	147.0	128.0	76.9	447.0	74.0	389.0	385.0
12:21	11.5	19.0	51.6	6.53	6.74	6.56	26.4	19.5	11.7	374.0	377.0	40.8	0.99	172.0	127.0	76.2	460.0	76.0	389.0	385.0
12:25	11.5	18.3	51.5	6.54	6.75	6.57	25.2	18.3	11.7	362.0	363.0	33.3	1.00	164.0	121.0	76.6	485.0	78.0	389.0	385.0
12:32	11.4	17.2	51.2	6.51	6.71	6.53	25.2	15.3	11.8	337.0	340.0	44.6	0.99	162.0	98.7	76.6	526.0	82.0	389.0	385.0
12:36	11.3	17.1	51.1	6.47	6.67	6.5	25.1	15.1	11.7	331.0	335.0	50.3	0.99	160.0	96.0	75.6	548.0	85.0	389.0	385.0
12:40	11.3	17.2	50.9	6.47	6.67	6.5	26.0	15.0	11.7	333.0	339.0	62.0	0.98	164.0	93.1	75.4	570.0	89.0	389.0	385.0
12:47	11.4	18.6	50.9	6.47	6.68	6.51	28.6	15.6	13.4	355.0	366.0	86.9	0.97	179.0	89.8	86.2	611.0	98.0	389.0	385.0
12:51	11.4	19.8	50.8	6.47	6.68	6.51	30.5	17.6	13.5	373.0	389.0	110.0	0.96	190.0	95.3	87.3	635.0	105.0	389.0	385.0
12:55	11.4	0.2	51.0	6.49	6.7	6.52	0.2	0.2	0.1	1.9	3.3	2.7	0.58	1.0	0.6	0.4	655.0	111.0	389.0	385.0
13:2	11.5	19.9	51.2	6.54	6.75	6.58	27.0	19.6	13.8	395.0	396.0	16.1	1.00	176.0	129.0	90.0	688.0	113.0	396.0	395.0
13:6	11.4	19.8	51.1	6.48	6.69	6.52	27.4	19.2	13.6	389.0	389.0	25.2	1.00	178.0	123.0	87.9	714.0	115.0	396.0	395.0
13:10	11.3	0.2	50.8	6.46	6.67	6.49	0.2	0.2	0.1	1.9	3.2	2.6	0.59	1.0	0.6	0.4	730.0	116.0	396.0	395.0

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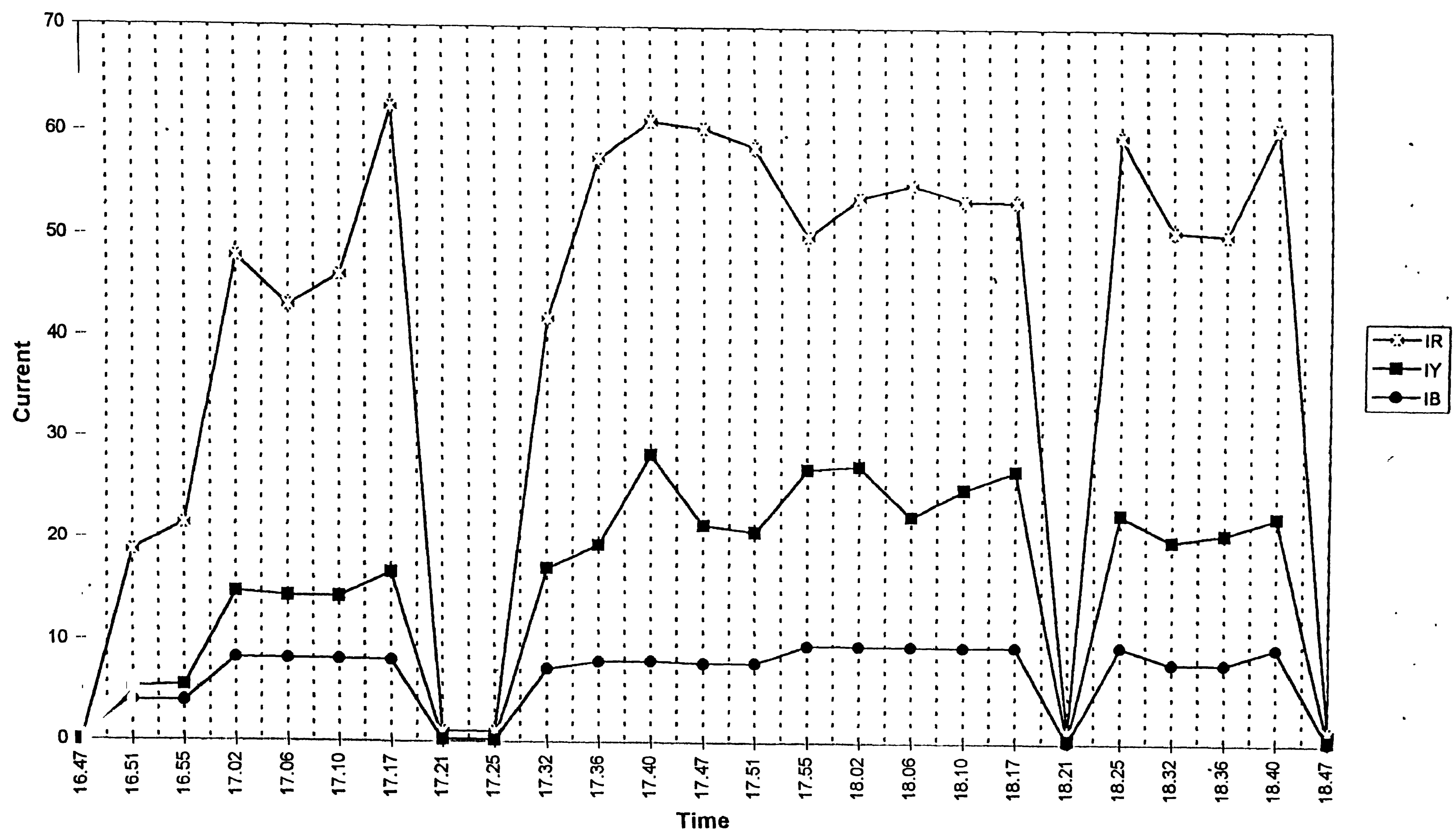
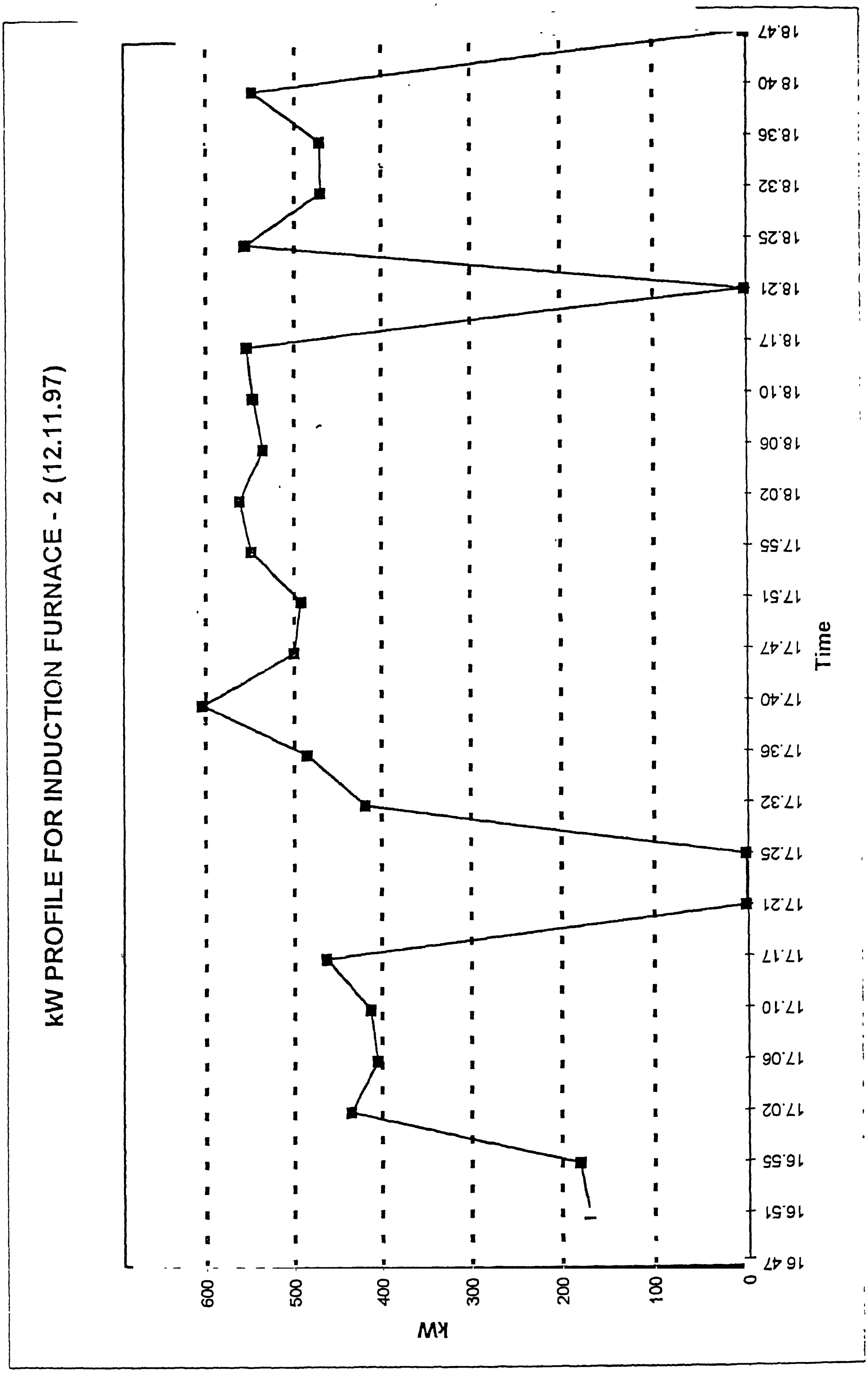
CURRENT PROFILE FOR INDUCTION FURNACE - 2 (12.11.97)

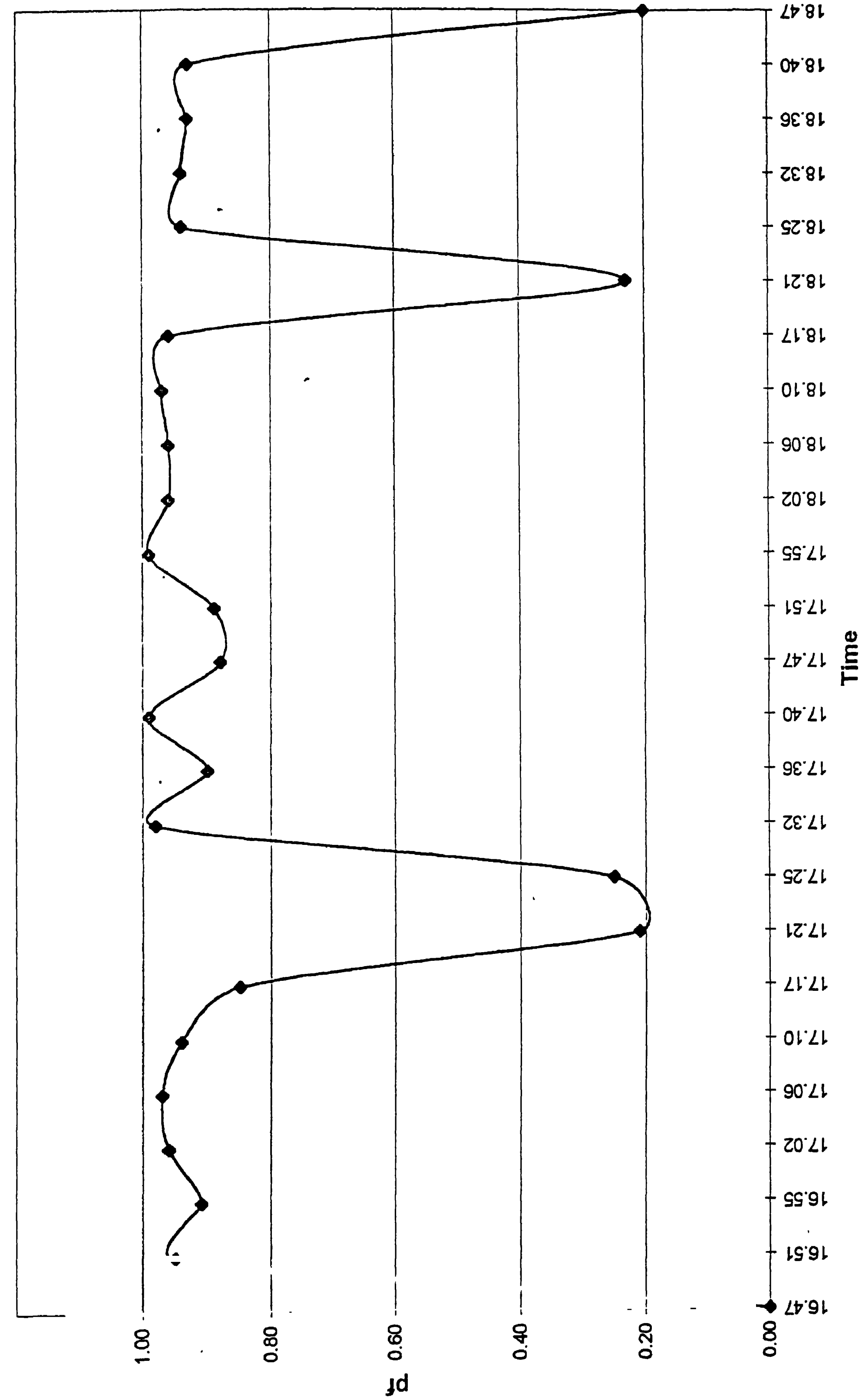


APPENDIX - 7/1-b



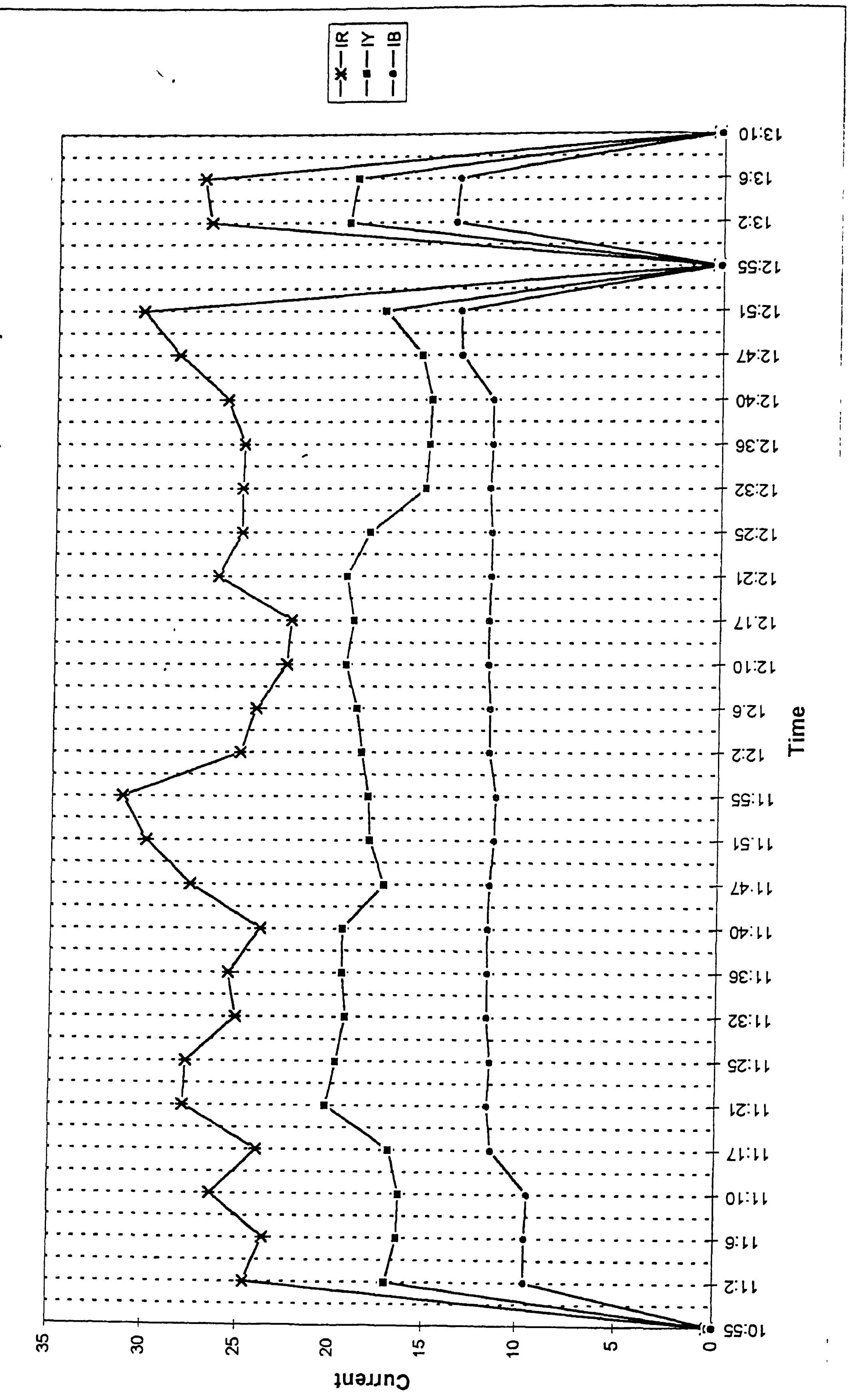
APPENDIX - 7/1-c

pf PROFILE FOR INDUCTION FURNACE - 2 (12.11.97)

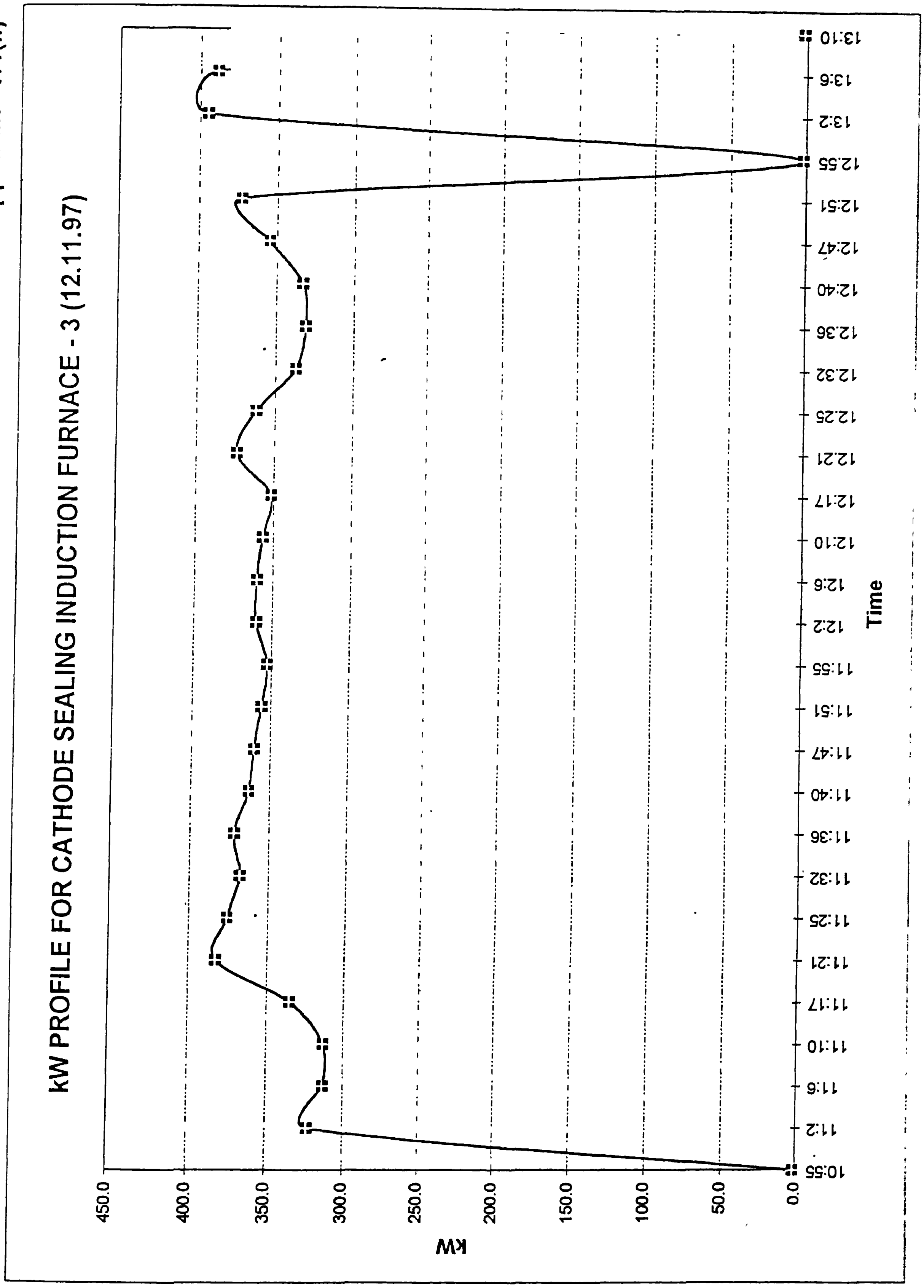


Appendix - 7/1- (i)

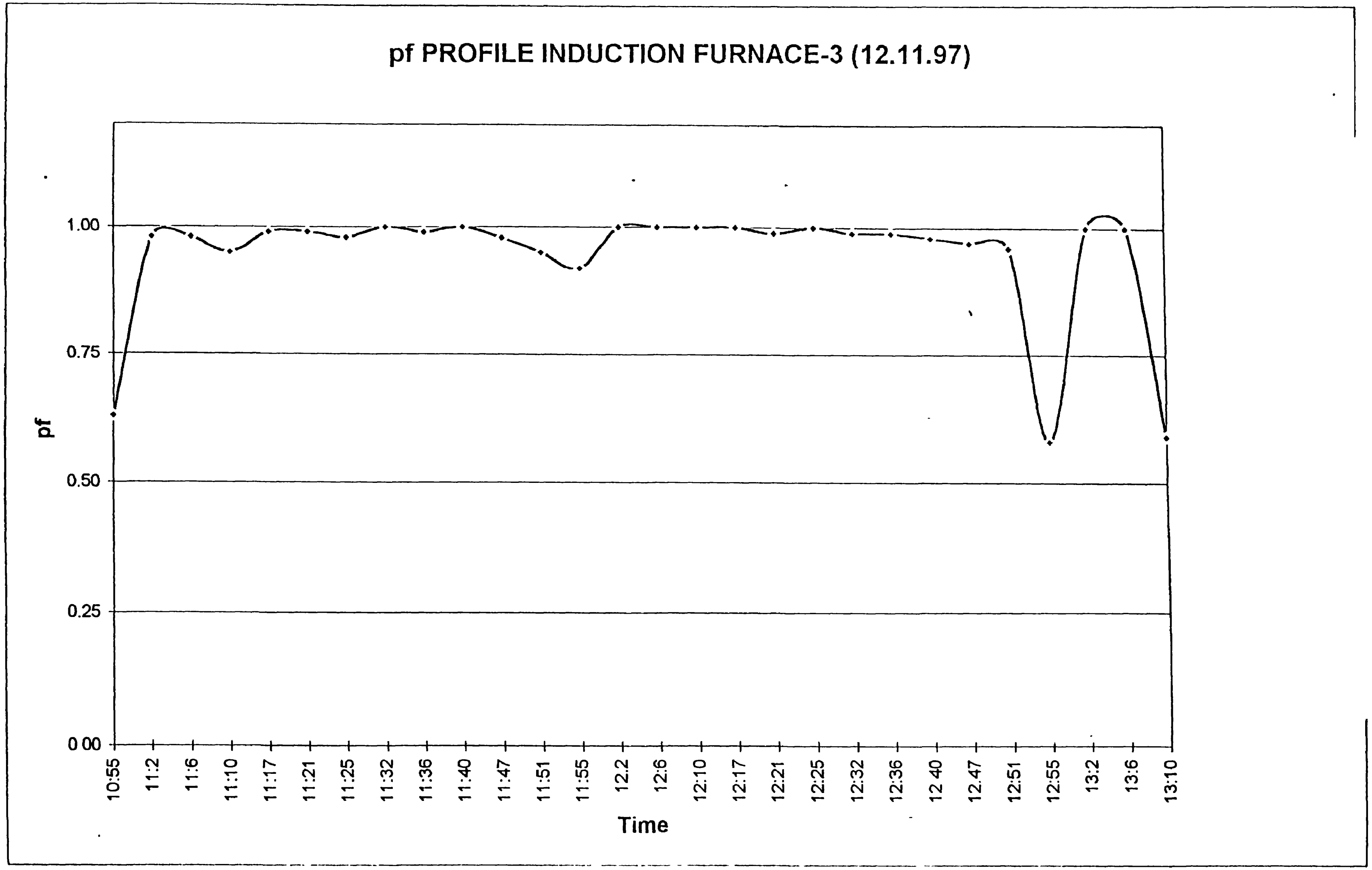
CURRENT PROFILE FOR INDUCTION FURNACE - 3 (12.11.97)



Appendix - 7/1(ii)



Appendix - 7/1 (iii)



Appendix - 7/2 contd.

OBSERVATIONS DURING CYCLE FOR INDUCTION FURNACE : 2

Date : 12.11.97

Time	Observations
	I - Cycle
14.15	Solid metal charged
14.22	Manual charge feeding is under process. Current compensation has been done. Tap position changed to 5.
14.40	Due to high water temperature, furnace tripped
14.41	Tap position changed to 4
16.15	'Si' addition (2 shovels)
16.21	Ready for tilting, tap settings changed to low.
16.34	Tap position changed to 5 high, after tilting
	II - Cycle
16.39	Raw material small quantity charged
16.47	First bucket charged (Thimble & Pig Iron)
16.48	During material charge furnace switched 'OFF'
16.49	Tap position - 6
16.55	Tap position - 4
17.15	Furnace switched 'OFF' (operational problem)
17.24	Furnace started
17.25	Tap position - 3
17.26	Second Bucket material charged, hood opened
17.40	Hood has been closed
17.45	Tap position - 1
17.48	Pushing Thimbles inside
17.56	Intermediate pushing and charging of material. Phase current compensation done manually.
18.12	Furnace switched 'OFF' 15 shovels of slag removed flux added to remove stage
18.17	2-shovels of slag removed. Furnace switched 'ON'
18.20	Tap position changed to '3' for temperature rise.
18.29	Tap position - 1
18.37	'Si' addition, measured liquid bath temperature 1555 C
18.40	Furnace switched 'OFF'. Tilting started.
18.42	Furnace tilted for 160 Sec.

APPENDIX - 7/2

OBSERVATIONS DURING CYCLE FOR INDUCTION FURNACE : III

Date : 12.11.97

Time	Observations
	I - Cycle
9.13	After charging material, tap position'7'
9.26	Pig Iron material inside heel, fumes coming out
9.35	Switched off for material charge. Manually material charge done. After 1 minute switched 'ON' to same tap.
9.46	After solid metal with liquid bath tap position '2' (800 V, 300 kW, 0.95, 180 A, 180A, 210A)
10.03	Tap position '3' (890 V, 360 kW, 0.98, 210A, 210A,. 220A)current compensation adjusted.
10.09	9 shovels of slag in 3-min.
10.16	7 shovels of slag in 2-min.
	1 shovels of slag
10.25	Flux added to remove slag
10.27	After flux addition 6 shovels of slag removed.
10.28	3-shovel of Silicon added
10.39	Liquid bath temp. 1550^{0}C
10.41	Metal tapping has done
10.44	Furnace has tilted
	II - Cycle
10.47	Furnace off. Material charge started (Thimble)
10.50	Furnace started, hood partially closed
11.02	Material charged (Pig Iron and Thimble),.furnace switched off.
11.03	Furnace switched on Tap position - 2 current compensation has been done
11.12	To tap position - 3 charged Material composition 70% Thimble + 20% Pig Iron
11.30	Furnace No.2 liquid ready for tapping, tap position changed to low.
11.35	Current compensation done
11.45	Flux powder added to break slag
12.10	Second bucket material charged (Thimble)
12.15	Hood opened partially
12.37	Pushing Thimble to inside liquid for 6 min
12.42	6 - shovels of slag removed in 3 min.
12.44	Flux added to remove slag.
	9 - shovels of slag removed in 3 min.
	Furnace switched 'OFF'
12.49	Furnace switched 'ON', current compensation has done
13.00	Measured liquid both temp.1552^{0}C, tap changed to low position.
13.30	Furnace switched 'OFF'

APPENDIX - 7/3

MONITORED PLANT METERING SYSTEM

Furnace No. : III
Date : 12.11.97

Time	Current			pf	Power	Voltage	Tap No.
	A_1	A_2	A_3	Cos ϕ	kW	V	
10.50	260	230	220	0.95	330	800	2 high
11.03	250	230	250	0.99	350	800	2 high
11.12	260	260	250	0.99	390	880	3 high
11.30	190	240	250	0.99	380	880	3 high
11.35	250	220	240	0.99	370	860	3 high
12.10	250	240	240	0.99	380	880	3 high
12.30	230	210	240	0.99	360	860	3 high
12.45	310	240	240	0.99	380	860	3 high
12.50	250	260	250	0.99	400	880	3 high
13.00	0	130	100	0.95	80	340	3 low
13.30	0	0	0	0.93	-	0	1 off

Furnace No. : II
Date : 12.11.97

Time	Current			Voltage	pf	Power	Tap No.
	R	Y	B	V	Cos ϕ	kW	
14.15	220	160	200	650	-	150	7 High
14.24	200	225	280	770	-	330	5 High
14.32	280	280	280	960	-	420	3 High
14.42	240	280	270	920	-	380	4 High
14.45	100	50	80	350	-	18	4 High
15.15	90	50	80	350	-	18	4 High
15.37	260	250	240	800	-	300	6 High
16.00	270	230	220	825	-	340	6 High
16.13	280	260	240	850	-	320	5 High
16.20	320	265	240	850	-	290	5 High
16.35	Switched OFF						
16.39	150	125	180	650	-	80	7 High
16.49	280	250	250	820	-	280	6 High
16.55	280	260	250	925	-	340	4 High
17.10	390	300	260	900	-	320	4 High
17.25	325	270	280	950	-	380	3 High
17.45	280	310	305	1150	-	480	1 High
17.57	290	300	310	1150	-	480	1 High
18.17	310	300	310	1150	-	450	1 High
18.20	290	270	280	950	-	360	3 High
18.29	318	285	305	1140	-	450	1 High
18.37	310	310	310	1150	-	475	1 High
18.40	Furnace tilted						

APPENDIX -7/4
Sht. 1 of 3

POWER MEASUREMENT OF CATHODE SEALING INDUCTION FURNACE HEAT CYCLE

TIME	V	I	Hz	V_R	V_Y	V_B	I_R	I_Y	I_B	kW	kVA	kVAr	Cos ϕ	kW_R	kW_Y	kW_B	kWh	kVArh	kVA (Peak)	kW (Peak)
11.03	356.4	78.0	50.8	204.5	208.2	205.5	111.0	70.9	58.7	46.6	48.2	12.2	0.97	21.2	13.5	11.9	0.0	0.0	0.0	0.0
11.05	357.3	77.6	50.9	204.5	208.2	205.5	109.0	71.5	58.6	46.5	48.0	11.7	0.97	20.8	13.8	11.9	1.5	0.4	0.0	0.0
11.11	356.4	73.4	50.9	204.5	208.2	205.5	91.4	75.0	65.6	45.4	45.4	74.2	1.00	17.5	14.5	13.3	6.2	1.0	0.0	0.0
11.15	357.3	73.4	50.9	204.5	208.2	205.5	92.2	74.9	65.6	45.4	45.4	74.0	1.00	17.6	14.5	13.4	9.2	1.0	0.0	0.0
11.20	357.3	73.4	50.9	205.5	208.2	206.4	92.0	76.4	65.5	45.5	45.5	74.1	1.00	17.5	14.5	13.4	13.0	1.0	0.0	0.0
11.32	877.3	181.0	50.8	499.1	514.5	506.4	202.0	187.0	165.0	274.5	274.5	735.8	1.00	99.1	91.8	83.9	60.2	1.2	274.5	274.5
11.36	859.1	175.0	50.7	488.2	503.6	495.5	204.0	177.0	162.0	259.1	260.0	12.5	1.00	95.5	84.5	79.4	77.7	1.7	274.5	274.5
11.40	861.8	174.0	50.9	490.0	504.5	497.3	194.0	186.0	162.0	260.0	260.0	728.4	1.00	91.8	87.5	79.9	94.9	2.2	274.5	274.5
11.47	873.6	178.0	51.5	498.2	512.7	501.8	162.0	230.0	165.0	261.8	270.0	791.4	-0.97	79.9	100.0	81.7	125.6	2.2	274.5	274.5
11.51	872.7	177.0	51.5	498.2	509.1	504.5	206.0	200.0	132.0	268.2	268.2	2.9	1.00	101.8	100.0	65.6	143.0	2.3	274.5	274.5
11.55	869.1	173.0	51.3	496.4	506.4	502.7	207.0	187.0	132.0	260.9	260.9	4.7	1.00	101.8	93.6	65.4	160.8	2.5	274.5	274.5
12.02	869.1	191.0	51.2	497.3	505.5	502.7	229.0	212.0	132.0	287.3	288.2	23.5	1.00	112.7	108.2	65.5	191.9	3.2	288.2	287.3
12.06	869.1	182.0	51.3	495.5	506.4	503.6	233.0	186.0	132.0	273.6	274.5	19.0	1.00	114.5	93.6	65.4	210.3	4.4	288.2	287.3
12.10	871.8	183.0	51.4	497.3	508.2	504.5	226.0	191.0	132.0	274.5	275.5	23.3	1.00	111.8	97.3	65.7	228.6	5.5	288.2	287.3
12.17	866.4	181.0	51.4	494.5	504.5	501.8	225.0	190.0	132.0	270.9	270.9	9.5	1.00	110.9	95.5	64.8	256.3	7.1	288.2	287.3
12.21	869.1	181.0	51.5	495.5	506.4	502.7	217.0	195.0	131.0	270.9	271.8	749.5	1.00	107.3	98.2	65.2	274.4	7.5	288.2	287.3
12.25	870.9	180.0	51.6	496.4	507.3	503.6	214.0	199.0	132.0	270.9	270.9	5.2	1.00	105.5	100.0	65.5	292.5	7.5	288.2	287.3
12.32	870.9	188.0	51.5	498.2	506.4	503.6	221.0	223.0	133.0	283.6	283.6	7.2	1.00	108.2	110.0	65.5	319.8	8.0	288.2	287.3
12.36	862.7	182.0	51.0	490.9	502.7	500.0	238.0	179.0	131.0	269.1	272.7	40.7	0.99	115.5	89.1	64.5	338.4	9.2	288.2	287.3
12.40	860.9	184.0	51.0	490.0	500.9	500.0	245.0	177.0	131.0	269.1	273.6	50.2	0.98	117.3	86.9	64.5	356.1	12.4	288.2	287.3
12.47	867.3	181.0	51.2	496.4	505.5	500.9	207.0	210.0	133.0	271.8	271.8	4.3	1.00	101.8	104.5	65.2	388.1	16.6	288.2	287.3
12.51	867.3	180.0	51.1	495.5	505.5	500.9	204.0	210.0	133.0	270.0	270.0	1.5	1.00	100.0	103.6	65.4	406.1	16.7	288.2	287.3
15.55	871.8	178.0	51.2	498.2	508.2	503.6	199.0	212.0	132.0	269.1	269.1	2.4	1.00	98.2	105.5	65.6	417.8	16.9	288.2	287.3
13.02	880.9	184.0	51.7	504.5	514.5	507.3	175.0	245.0	133.0	264.5	280.9	736.5	-0.94	82.9	114.5	66.9	452.3	16.9	288.2	287.3
13.06	875.5	171.0	52.0	500.0	511.8	504.5	178.0	214.0	137.0	257.3	260.0	764.9	-0.99	87.5	100.9	68.4	469.6	17.3	288.2	287.3
13.10	360.9	75.3	52.1	207.3	210.9	208.2	83.8	87.9	54.8	45.0	47.1	741.1	-0.96	16.6	17.2	11.3	475.9	17.3	288.2	287.3
13.17	361.8	74.2	51.9	207.3	210.9	208.2	92.2	87.1	54.9	46.4	46.5	75.7	1.00	18.1	17.0	11.3	480.5	17.3	288.2	287.3
13.21	361.8	78.4	51.9	207.3	210.9	208.2	97.8	89.1	55.3	47.4	49.1	12.9	0.97	18.9	17.1	11.4	483.6	17.6	288.2	287.3

POWER MEASUREMENT OF CATHODE SEALING INDUCTION FURNACE HEAT CYCLE

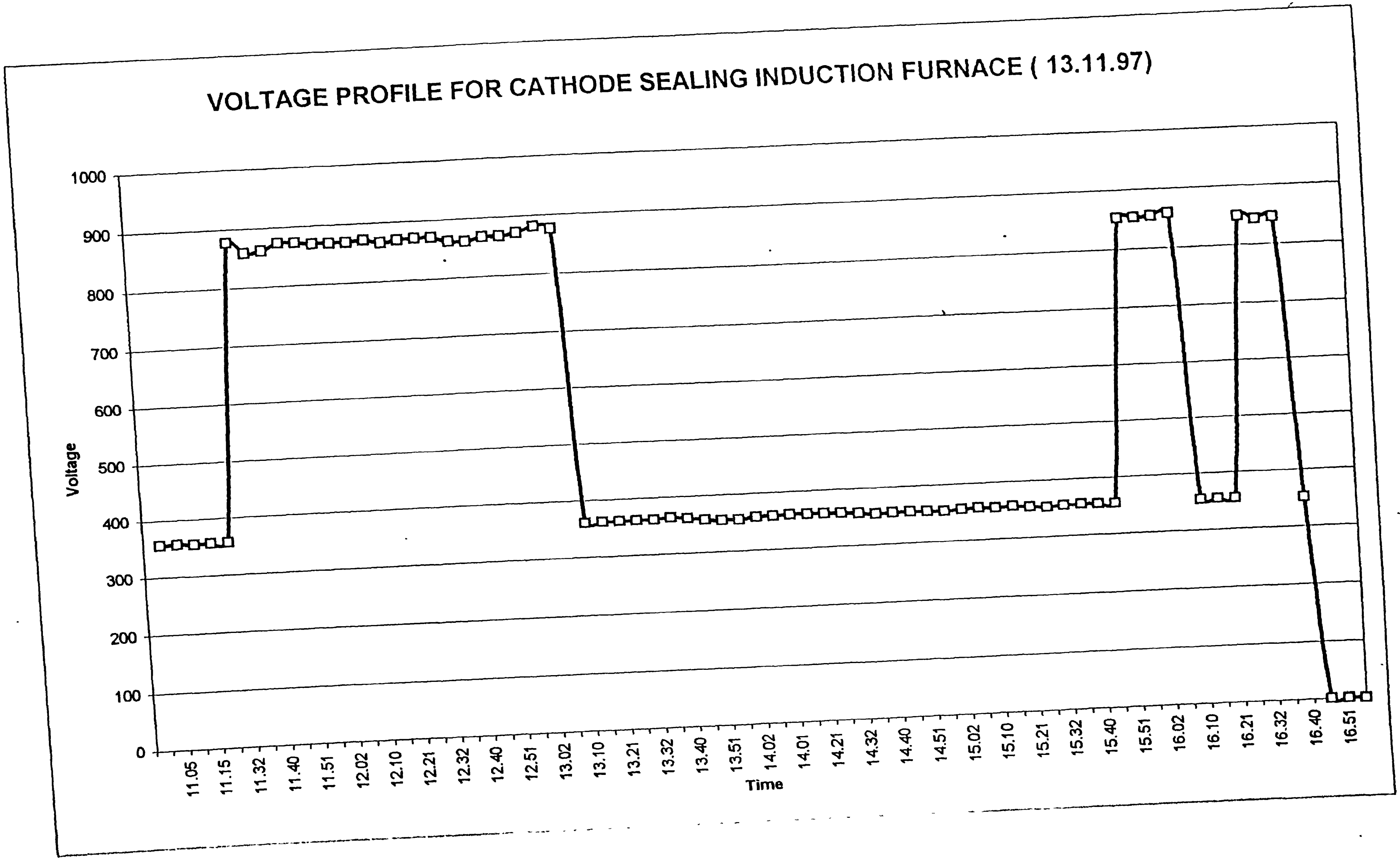
TIME	V	I	Hz	V_R	V_Y	V_B	I_R	I_Y	I_B	kW	kVA	kVAr	Cos ϕ	kW_R	kW_Y	kW_B	kWh	kVArh	kVA (Peak)	kW (Peak)
13.25	361.8	78.1	51.7	207.3	210.9	208.2	99.9	85.2	55.1	47.5	49.0	11.5	0.97	19.6	16.5	11.4	486.8	18.1	288.2	287.3
13.32	361.8	80.0	51.6	207.3	210.9	209.1	106.0	84.4	55.3	48.6	50.2	12.5	0.97	20.9	16.4	11.4	492.5	19.5	288.2	287.3
13.36	363.6	78.6	51.8	208.2	211.8	209.1	99.4	86.5	55.4	48.2	49.5	11.0	0.98	19.7	17.0	11.5	495.7	20.3	288.2	287.3
13.40	361.8	77.8	52.1	207.3	210.9	209.1	93.6	90.7	55.2	47.5	48.8	10.9	0.98	18.5	17.8	11.3	499.0	20.8	288.2	287.3
13.47	357.3	80.0	51.3	204.5	208.2	206.4	111.0	79.6	54.6	48.2	49.5	10.9	0.98	21.7	15.4	11.1	504.5	21.5	288.2	287.3
13.51	355.5	83.6	50.8	202.7	207.3	205.5	125.0	80.1	54.5	48.6	51.5	16.7	0.95	23.6	13.9	11.1	507.7	22.4	288.2	287.3
13.55	355.5	84.6	50.8	203.6	207.3	205.5	127.0	82.0	54.7	48.9	52.1	17.9	0.94	23.8	14.0	11.1	511.0	23.6	288.2	287.3
14.02	358.2	83.0	51.0	205.5	209.1	206.4	110.0	85.9	54.9	49.1	51.5	15.5	0.95	21.4	16.5	11.2	517.4	25.7	288.2	287.3
14.06	359.1	79.9	51.3	206.4	209.1	207.3	101.0	87.7	55.1	48.9	49.7	9.3	0.98	20.1	17.5	11.3	520.6	26.5	288.2	287.3
14.01	360.0	79.9	51.5	206.4	210.0	207.3	98.7	90.7	55.1	48.7	49.8	10.2	0.98	19.5	18.0	11.3	523.9	27.2	288.2	287.3
14.17	360.0	79.9	51.7	206.4	210.0	207.3	96.3	93.4	55.0	48.6	49.8	10.7	0.98	19.0	18.5	11.3	528.8	28.0	288.2	287.3
14.21	359.1	81.1	51.3	205.5	209.1	206.4	104.0	89.5	55.0	49.1	50.4	11.1	0.98	20.4	17.5	11.3	532.1	28.7	288.2	287.3
14.25	358.2	81.8	51.1	205.5	208.2	206.4	108.0	87.8	54.8	49.3	50.7	12.1	0.97	21.2	16.9	11.2	535.5	29.5	288.2	287.3
14.32	356.4	81.9	50.9	204.5	207.3	205.5	111.0	85.5	54.8	49.2	50.5	11.6	0.97	21.6	16.5	11.1	541.2	30.9	288.2	287.3
14.36	354.5	81.9	50.9	203.6	206.4	204.5	112.0	85.0	54.4	48.8	50.4	12.2	0.97	21.7	16.1	11.0	544.5	31.6	288.2	287.3
14.40	355.5	82.4	50.9	203.6	207.3	204.5	113.0	85.6	54.5	49.1	50.7	12.6	0.97	21.8	16.2	11.1	547.7	32.5	288.2	287.3
14.47	355.5	83.3	50.8	203.6	207.3	204.5	116.0	85.4	54.5	49.3	51.2	13.8	0.96	22.4	15.9	11.1	553.5	33.9	288.2	287.3
14.51	354.5	85.2	50.3	203.6	206.4	203.6	91.8	111.0	54.7	48.9	52.3	745.7	-0.94	16.8	21.1	11.1	556.8	34.8	288.2	287.3
14.55	353.6	80.3	50.1	202.7	206.4	203.6	95.0	105.0	54.8	49.1	49.1	73.7	1.00	17.9	20.2	11.0	560.2	35.1	288.2	287.3
15.02	355.5	85.7	49.3	203.6	207.3	204.5	113.0	94.2	55.7	51.3	52.7	12.5	0.97	21.8	18.2	11.3	566.6	36.5	288.2	287.3
15.06	356.4	83.9	49.7	204.5	208.2	205.5	101.0	99.1	55.7	50.8	51.8	10.2	0.98	19.9	19.6	11.3	570.1	37.2	288.2	287.3
15.10	355.5	83.5	49.9	203.6	207.3	204.5	98.0	102.0	55.5	50.3	51.5	10.9	0.98	19.0	20.1	11.2	573.5	37.5	288.2	287.3
15.17	356.4	83.4	49.8	204.5	207.3	205.5	98.8	99.8	55.3	50.5	51.5	10.1	0.98	19.4	19.8	11.3	578.5	37.8	288.2	287.3
15.21	354.5	87.3	49.1	202.7	206.4	204.5	116.0	92.1	55.4	51.3	53.5	15.5	0.96	22.5	17.5	11.2	581.9	38.5	288.2	287.3
15.25	352.7	88.2	48.8	201.8	205.5	203.6	125.0	92.1	55.4	51.4	53.8	15.9	0.96	23.6	16.6	11.2	585.4	39.5	288.2	287.3
15.32	354.5	82.3	49.5	203.6	206.4	204.5	105.0	94.7	55.1	50.5	50.5	1.0	1.00	20.7	18.6	11.2	591.4	41.1	288.2	287.3
15.36	355.5	81.8	49.7	203.6	207.3	204.5	100.0	101.0	55.1	50.3	50.3	74.6	1.00	19.4	19.6	11.2	594.7	41.2	288.2	287.3
15.40	354.5	81.8	49.8	203.6	207.3	204.5	99.3	99.8	55.1	50.3	50.3	0.9	1.00	19.4	19.7	11.2	598.1	41.2	288.2	287.3

Appendix - 7/4 contd..
Sht. 3 of 3

POWER MEASUREMENT OF CATHODE SEALING INDUCTION FURNACE HEAT CYCLE

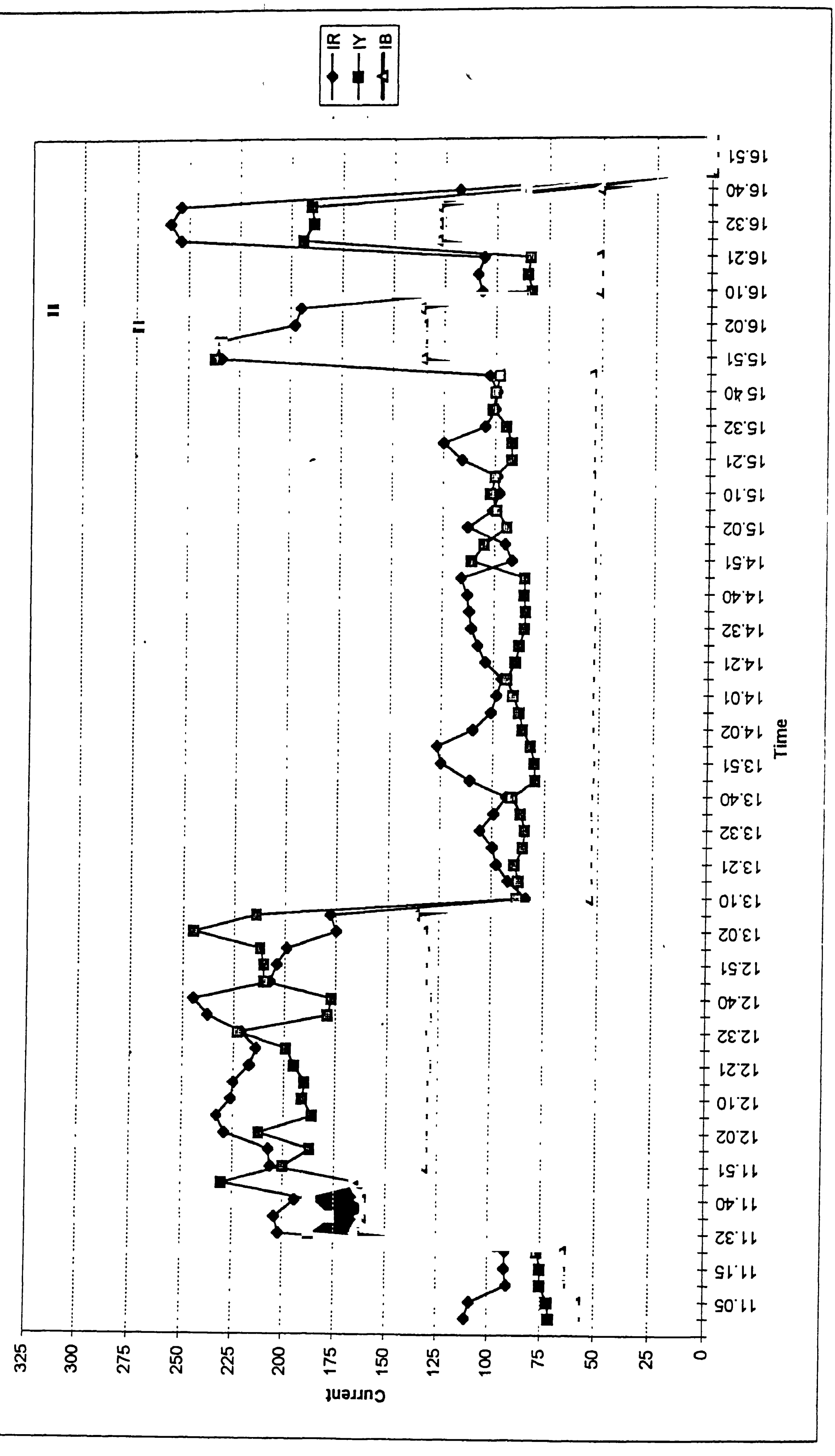
TIME	V	I	Hz	V_R	V_Y	V_B	I_R	I_Y	I_B	kW	kVA	kVAr	Cos ϕ	kW_R	kW_Y	kW_B	kWh	kVArh	kVA (Peak)	kW (Peak)
15.47	354.5	82.3	49.5	202.7	206.4	204.5	103.0	97.9	55.3	50.5	50.5	0.8	1.00	20.2	19.2	11.2	604.0	41.5	288.2	287.3
15.51	852.7	202.0	49.2	488.2	496.4	492.7	234.0	237.0	136.0	299.1	299.1	730.7	1.00	114.5	117.3	67.0	612.0	41.7	288.2	287.3
15.55	852.7	202.0	49.1	487.3	496.4	492.7	236.0	234.0	136.0	298.2	298.2	730.5	1.00	115.5	116.4	66.8	631.9	42.3	288.2	287.3
16.02	854.5	200.0	50.0	490.0	498.2	490.9	198.0	274.0	136.0	288.2	296.4	795.0	-0.97	91.8	130.0	66.5	670.1	42.4	299.1	299.1
16.06	859.1	208.0	50.6	494.5	500.9	491.8	195.0	315.0	137.0	285.5	310.0	739.4	-0.92	77.0	141.8	66.8	689.1	42.4	299.1	299.1
16.10	354.5	79.2	50.8	202.7	206.4	204.5	107.0	83.1	52.4	47.6	48.6	9.8	0.98	20.9	16.2	10.6	692.9	43.0	299.1	299.1
16.17	355.5	80.6	50.9	203.6	207.3	204.5	109.0	84.9	52.5	48.3	49.5	11.1	0.98	21.2	16.5	10.6	697.7	43.8	299.1	299.1
16.21	354.5	79.5	50.9	203.6	206.4	204.5	106.0	83.7	52.5	48.0	48.8	9.0	0.98	20.9	16.5	10.6	701.0	44.1	299.1	299.1
16.25	849.1	190.0	50.8	484.5	493.6	492.7	254.0	194.0	129.0	279.1	280.0	26.1	1.00	121.8	93.6	63.0	713.6	45.3	299.1	299.1
16.32	843.6	192.0	50.6	480.9	490.9	490.0	259.0	189.0	129.0	273.6	280.0	59.5	0.98	121.8	89.4	62.1	746.2	49.8	299.1	299.1
16.36	845.5	188.0	50.7	481.8	491.8	490.9	254.0	190.0	129.0	274.5	276.4	30.5	0.99	120.9	90.9	62.4	764.3	52.8	299.1	299.1
16.40	350.9	83.2	50.6	200.9	204.5	202.7	118.0	86.1	51.9	48.5	50.5	14.4	0.96	22.5	15.6	10.5	768.5	53.8	299.1	299.1
16.47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	772.4	55.0	299.1	299.1
16.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	772.4	55.0	299.1	299.1
16.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	772.4	55.0	299.1	299.1

APPENDIX - 7/4-a



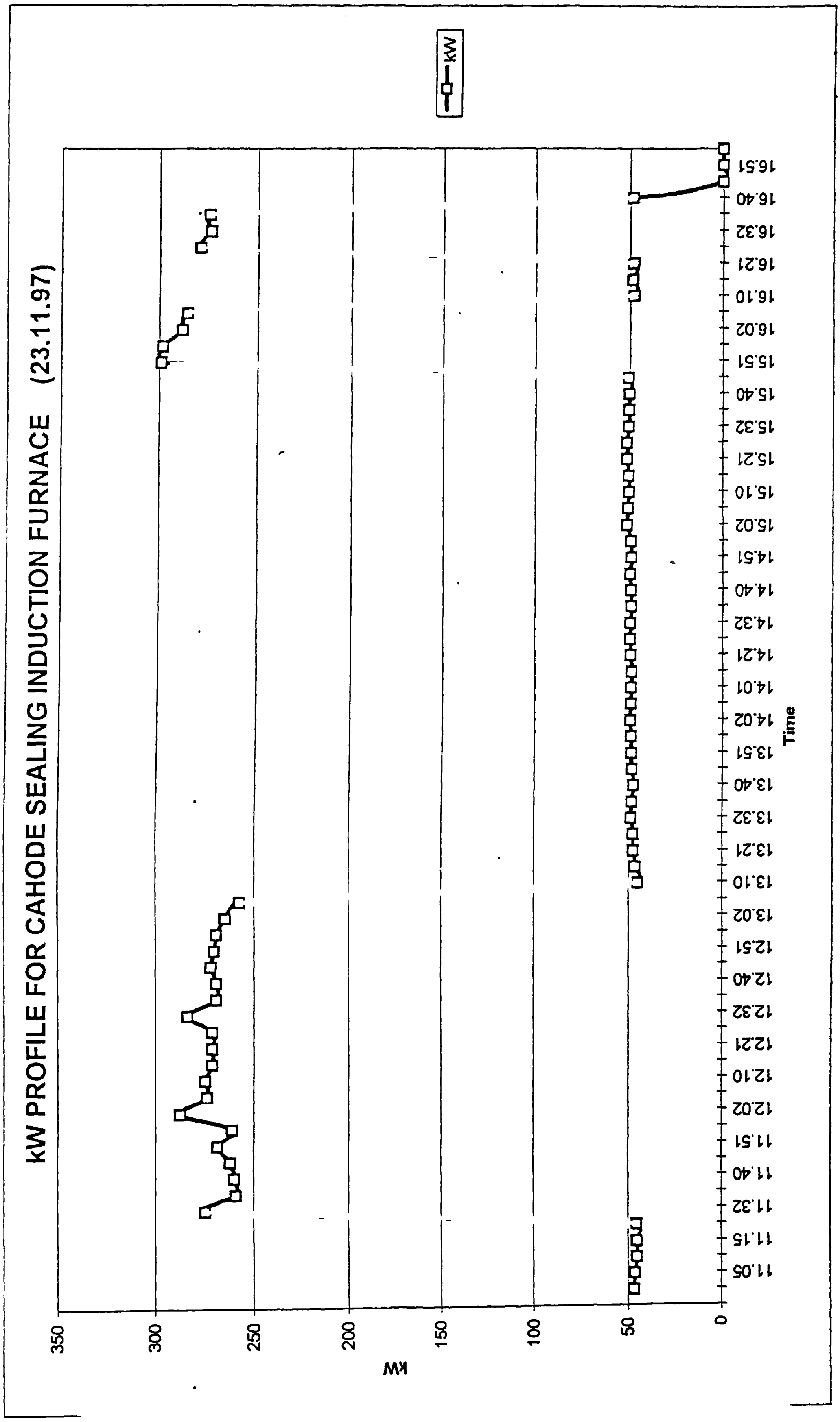
APPENDIX - 7/4- b

CURRENT PROFILE FOR CATHODE SEALING INDUCTION FURNACE (13.11.97)



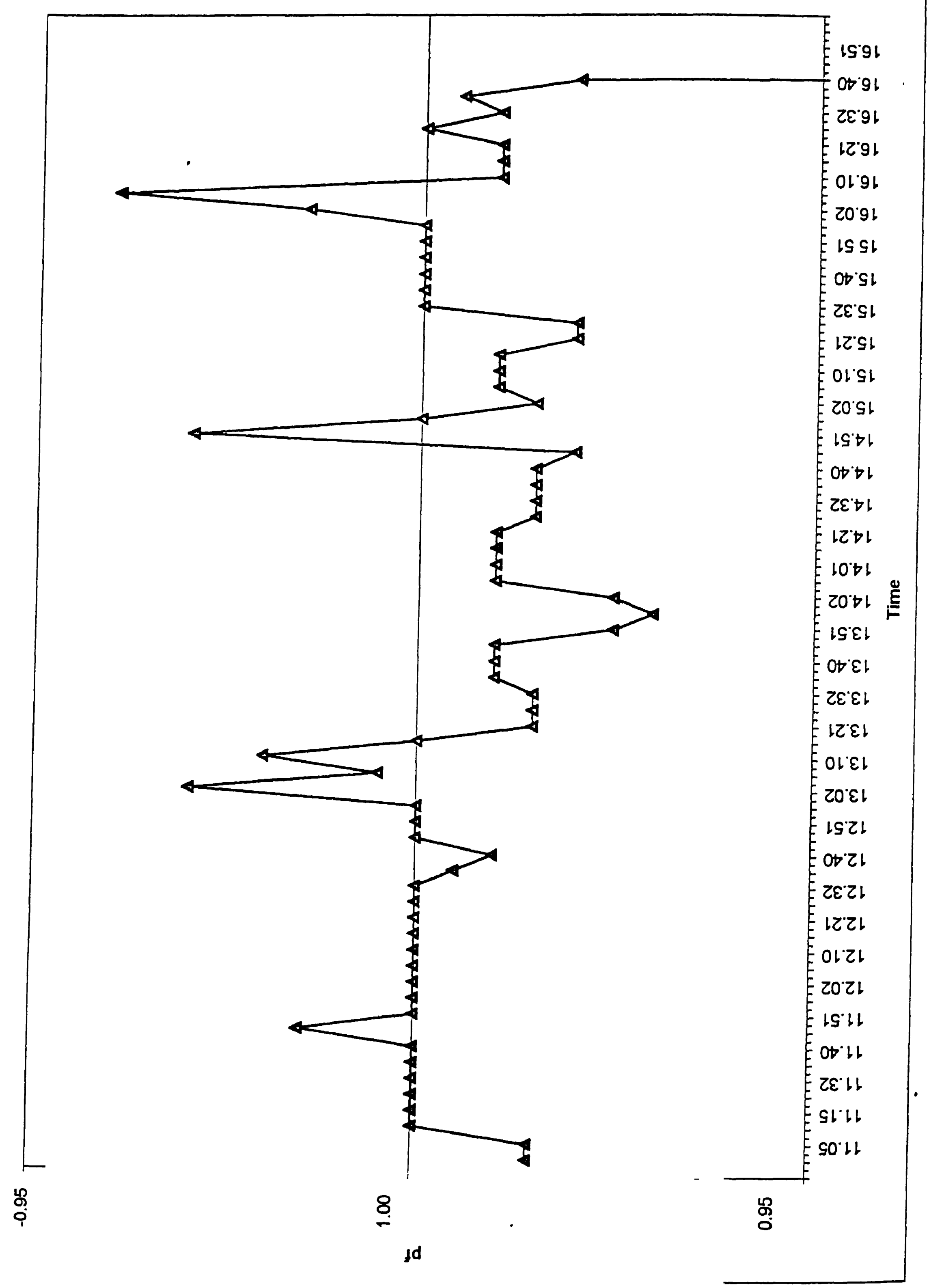
teri

APPENDIX - 7/4-c



APPENDIX - 7/4 - d

pf PROFILE FOR CATHODE SEALING INDUCTION FURNACE (13.11.97)



APPENDIX - 7/5

MONITORED PLANT METERING SYSTEM

Furnace : Cathode Sealing Area
Date : 13.11.97

Time	Current			Voltage	pf	Power	Tap No.
	R	Y	B	V	Cos ϕ	kW	
8.00	90	80	100	350	0.99	40	2 Low
9.00	250	180	250	840	0.93	320	2 High
~~10.50~~	~~100~~	~~75~~	~~100~~	~~350~~	~~0.99~~	~~40~~	~~2 Low~~
11.20	200	190	290	850	0.97	320	2 High
12.00	220	180	220	850	0.97	320	2 High
12.20	220	200	230	850	0.98	320	2 High
12.45	250	180	230	840	0.96	318	2 High

APPENDIX - 7/6

OBSERVED COOLING WATER TEMPERATURES IN INDUCTION FURNACE COIL

Date : 12.11.97 & 13.11.97

Furnace No. : III				Thermocouple position											
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11.00	52.9	48.8	46.2	47.4	47.7	50.8	44.8	51.1	53.2	49.6	50.1	50.4	47.5	49.4	-
12.00	51.6	51.6	51.5	52.8	53.0	56.3	46.9	55.8	58.4	53.9	56.3	52.5	52.4	46.7	-
Furnace No. : II															
17.00	49.2	47.4	49.2	49.6	48.8	57.6	48.4	50.9	47.8	49.9	-	52.2	-	49.9	49.4
17.30	51.8	48.1	52.5	53.5	51.6	61.6	55.3	52.5	56.9	56.6	-	54.9	-	54.4	54.4
Cathode Sealing Area															
11.10	39	39	41	41	39	38	40	40	40	39	39	40	39	38	37
12.10	50	47	52	52	54	56	59	57	58	58	54	57	52	55	42
12.45	50	47	52	53	54	56	59	58	60	58	53	56	52	55	44

APPENDIX - 8/1
Sht 1 of 5

LIST OF RETROFITS AND SUPPLIERS

Eqpt./Retrofit	Manufacturer
Energy Efficient Motors	Siemens Limited Jyothi Mahal II Floor St.Marks Road, Bangalore 560 001
	Crompton Greaves Limited Machine I Division Dr. E Moses Road Worli, Bombay 400 018
	Kirloskar Electric Company Post Box - 5555, Malleswaram West Bangalore - 560 055
	N G E F Ltd. PB-No. 3876, Byappanahalli Bangalore - 560 038
Variable Speed Drives	Asea Brown Boveri Ltd. Sona Towers, 71, Miller Road Bangalore 560 052
	Kirloskar Electric Co. Ltd. Unit-IV, Belawadi Ind. Area Mysore 510 005
	Siemens Limited Jyothi Mahal, III Floor -49 St.Marks Road, Bangalore 560 001
	Allen Bradley Ltd. C-11, Site-4 Industrial Area, Shahidabad Pin 201 010

Appendix - 8/1 contd..
Sht 2 of 5

Eqpt./Retrofit	Manufacturer
Soft Starters	Jeltron Instruments (I) (P) Ltd. 6-3-248/F Road No.1 Banjara Hills Hyderabad 500 034
	Jayshree Electro Devices (P) Ltd. 101, Prabhodhan Apartment 64/9, Erandewane, Pune 411 004
	Bharat Bijilee Ltd. Industrial Electronic Division 501-502, Swastik Chambers Chembur, Bombay 400 071
	Control Techniques (I) Ltd. 117-B, Developed Plot Industrial Estate Perungudi, Madras 600 096
Power Analyser (To measure kVA, kW, PF, V & A)	Microtek Instruments 40-A, I Main Road I Floor, CIT Nagar Madras 600 035
Star Delta Auto Controllers	Project & Supply A-605, Sunswept, Lokhandwala Complex Swami Samarth Nagar Four Bunglow, Andheri (W) Bombay 400 056

Eqpt./Retrofit	Manufacturer
	Technovation Control & Power Systems 5, Savita Sangam Society Near Rajesh Apartment, Gotri Road Baroda 390 007
	Integrated Drive Systems Pvt. Ltd 170, Raja Industrial Estate, P.K.Road, Mulund (W) Mumbai - 400 080
Micro Processor Based Energy Metering Systems	Sun electronic Technology Ltd Rep. Of Quad Logic System Inc. 177/2, Bilekahallil Bannerghatta Road Bangalore - 560 076
	Power Measurement India Pvt. Ltd. 12-G, Gopala Tower, 25, Rajendra Place New Delhi - 110 008
	Enercon Systems Pvt. Ltd. 47 & 47/1, II Floor, 6th Cross, (Opp, KSS Education Board) Malleswaram Bangalore - 560 003
	Alacrity Electronics Ltd. 85, 6th main Road, Malleswaram Bangalore - 560 003
	CDCON B-1, Shanti Villa Apartments, Pratapkunj society Vasana, Ahmedabad - 380 007

Appendix - 8/1 contd..
Sht 4 of 5

Eqpt./Retrofit	Manufacturer
Thermic Fluid Heaters	Thermax Limited Chinchwadi, Pune 411 019
	Energy Pack Boilers Pvt Ltd. 5, Prabhu Park Race Course Circle Baroda 390 007
Anemometer	Microtech Instruments 40-A, I Main Road CIT Nagar, Madras 600 035
Hoses and Clamps	Festo Controls Ltd Plot No. 226, Bommasandra Indl. Area, Attibele P.O Bangalore - 560 158
Synthetic Flat Belts	Habasit Iakoka Pvt. Ltd B-4, Gyan Towers 2 & 3, Gopala Krishna Iyer Street T.Nagar Madras - 600 017
	NTB International Ltd A-302, Road No.32 Wagle Industrial Estate Thane - 400 604
	Kunal Engineering Co. Ltd. Plot No.22, Industrial Estate Embitter Madras 600 058

Appendix - 8/1 contd..
Sheet 5 of 5

Eqpt./Retrofit	Manufacturer
Kry Kard Fuel Manager **Quintox 5006** **Combustion Gas Analyser**	Alactrity Electronics Ltd. ATANDARA 15, Thirumalai Road, T Nagar Chennai 600 017
Testo - 350 Flue Gas Analyser	SISKIN Instruments Co. (P) Ltd. 506, Sampige Road 11th Cross, Malleswaram Bangalore 560 003
	Testo GmbH & Co. Postfach1140 D-79849 Lenzkirch Telefon (07653) 681 - 0 Telefax (-7653) 681 100
`Al' Cladding	Beardsell Ltd. A-3/1, Glindal House 8, N.S.Road Calcutta - 700 001
Infrared Thermometer	Toshniwal Industries (P) Ltd. No.SF-4, Business Point 137, Brigade Road Bangalore - 560 025